BEFORE THE PUBLIC UTILITIES COMMISSION

OF THE STATE OF HAWAII

In the Matter of PUBLIC UTILITIES COMMISSION Instituting a Proceeding to Investigate the Implementation of Feed-in Tariffs	)))))))	DOCKET NO. 2008-0273

**COMMENTS OF ZERO EMISSIONS LEASING LLC
ON RELIABILITY STANDARDS**

AND

CERTIFICATE OF SERVICE

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COMMENTS OF ZERO EMISSIONS LEASING LLC
<u>ON RELIABILITY STANDARDS</u>

ZERO EMISSIONS LEASING LLC ("Zero Emissions") respectfully submits the following comments on the reliability standards contained in the Proposed Reliability Standards of Clean Energy Maui LLC ("Clean Energy Maui" or "CEM") and Zero Emissions Leasing LLC ("Zero Emissions" or "ZEL") filed on February 4, 2010 (the "CEM/ZEL Reliability Standards"), the reliability standards contained in Blue Planet Foundation's Reliability Standards filed on February 8, 2010 (the "BPF Reliability Standards"), and the HECO Companies' Reliability Standards Report filed by Hawaiian Electric Company, Inc. ("HECO"), Hawaii Electric Light Company, Inc. ("HELCO") and Maui Electric Company, Limited ("MECO") (HECO, HELCO and MECO collectively, the "HECO Companies") on February 8, 2010 (the "HECO RS Report"), as elaborated by the HECO Companies' proposal, filed February 26, 2010, to convene a Reliability Standards Working Group (the "HECO RSWG Proposal"), in the above-referenced proceeding:

I. OVERVIEW

In its Decision and Order filed September 25, 2009 (the "D&O"), the Commission stated that feed-in tariffs ("FITs") "were a possible mechanism 'to dramatically accelerate the addition of renewable energy from new sources' and to 'encourage increased development of alternative energy projects'." *D&O* at 13. The Commission said that it "will direct the HECO Companies to adopt FITs in their respective service territories ... consistent with the principles described below." *D&O* at 17. Those principles included a requirement that the HECO Companies "adopt standards that establish when additional renewable energy can or cannot be added on an island or region therein without markedly increasing curtailment, either for existing or new renewable projects. FIT generation should meet new load requirements and **displace fossil fuel generation** ... " [emphasis added] *D&O* at 50-51.

The National Renewable Energy Laboratory[1] has defined a "Feed-in Tariff (FIT)" as:

> A renewable energy policy that typically offers a **guarantee of:**
>
> **1.** **Payments** to project owners for total kWh of renewable electricity produced
>
> **2.** **Access to the grid**; and
>
> 3. Stable, long-term contracts (15-20 years) [emphasis in original]

Feed-in tariffs ("FITs") accelerate the addition of renewable energy from new sources and encourage increased development of alternative energy projects by obliging the utility to interconnect such projects (*i.e.*, a guarantee of access to the grid, provided

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[1] Karlynn Cory, "Renewable Energy Feed-in Tariffs: Lessons Learned from the U.S. and Abroad (National Renewable Energy Laboratory, November 18, 2009), accessed at http://www.cleanenergystates.org/Meetings/RPS_Summit_09/Cory_RPS_Summit2009.pdf.

the utility's reliability requirements are met), and by obliging the utility to purchase such renewable energy at a fixed long-term rate (*i.e.*, a guarantee of payments to project owners for total kWh of renewable electricity produced). FITs encourage accelerated development of renewable energy projects because these utility obligations give project developers the revenue certainty that they need to obtain financing for their projects.

FITs create revenue certainty by creating price certainty and quantity certainty. FITs create price certainty by specifying a fixed long-term rate at which the utility is obliged to purchase renewable energy. FITs create quantity certainty by obliging the utility to interconnect the renewable energy project (provided reliability requirements such as Rule 14H are met) for delivery of renewable energy to the utility, and by obliging the utility to purchase quantities of renewable energy generated by the project.

In creating a utility obligation under a FIT to interconnect as-available (intermittent) renewable energy generation (such as in-line hydropower, concentrating solar power, photovoltaic solar power and onshore windpower) to the utility's electric system, the Commission needs to know how much as-available renewable energy ***could*** be added to the grid of each island without compromising the reliability of the utility's electric system. The amount of as-available renewable energy that ***could*** be added to the grid of each island without compromising electric system reliability will depend on the regulating capacity of the utility's must-run and dispatchable ***non***-renewable (i.e., fossil fuel) generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation.

In creating a utility obligation to purchase as-available renewable energy, the Commission needs to know: Of the amount of as-available renewable energy that ***could*** be added to the grid of each island without compromising electric system reliability, how much of that amount ***should*** be added to the grid based on ***economic*** considerations? The amount of as-available renewable energy that ***should*** be added to the grid will depend on the economic costs and benefits of the added as-available renewable energy relative to any dispatchable non-renewable energy displaced by the added as-available renewable energy.

To determine a proper cap on the amount of as-available renewable energy that the utility should be obliged to purchase under a FIT, the Commission needs answers to the following two questions:

> **Question 1:** How much as-available renewable energy ***could*** be added to the grid of each island without compromising electric system reliability based on the regulating capacity of the utility's must-run and dispatchable non-renewable generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation?
>
> **Question 2:** How much of the as-available renewable energy that could be added to the grid of each island without compromising electric system reliability ***should*** the utility be obliged to purchase based on the relative costs and benefits of the added as-available renewable energy and any dispatchable non-renewable energy displaced by the added as-available renewable energy?

Because the answer to Question 2 depends on the answer to Question 1, the Commission needs an answer to Question 1 to determine a proper cap on the amount of as-available renewable energy that the utility should be obliged to purchase under a FIT. Without an answer to Question 1, any cap on the amount of such as-available renewable energy, such as the Commission's initial cap equal to 5% of 2008 peak demand (*D&O* at 55), will be based on a guess by the Commission as to the amount of as-available renewable energy that could be added to the grid of each island without compromising electric system reliability. Without an answer to Question 1, the effective cap on the amount of such as-available renewable energy will be zero because the Commission cannot be sure that ***any*** addition of as-available renewable energy will not compromise the reliability of the utility's electric system.

The Commission recognized early on that an answer to Question 1 was necessary for the Commission to make an informed determination of how much as-available renewable energy the utility should be obliged to purchase under a FIT. In PUC-IR-1, the Commission asked the Hawaiian Electric Companies:

> For each island, with the current levels of demand, transmission, and supply resources, what is the maximum amount of total and additional intermittent resources that can be accommodated without compromising reliability?

The Commission characterized the Hawaiian Electric Companies' response to PUC-IR-1 as follows (*D&O* at 49):

> Citing the multiplicity of factors incorporated into reliability determinations, the HECO Companies declined at the panel hearing and in their submissions to define how much renewable energy each island could incorporate.

As a result of the Hawaiian Electric Companies' refusal to answer Question 1 (as put to the Hawaiian Electric Companies in the form of PUC-IR-1), the Commission set an initial cap, on the amount of as-available renewable energy that the utility would be obliged to purchase under a FIT (*D&O* at 55), based on a guess that as-available renewable energy in an amount equal to 5% of 2008 peak system demand ***could*** be added to the grid of each island without compromising electric system reliability.

In directing the Hawaiian Electric Companies

> to develop reliability standards for each company, which should define most circumstances in which FIT projects can or cannot be incorporated on each island. ... The standards should complement existing standards, including those in the HECO Companies' tariff Rule 14, and should provide greater predictability with respect to reliability issues for developers. ... (*D&O* at 50)

and in directing the Hawaiian Electric Companies

> to adopt standards that establish when additional renewable energy can or cannot be added on an island or region therein without markedly increasing curtailment, either for existing or new renewable projects. FIT generation should meet new load requirements and **displace fossil fuel generation** ... " [emphasis added] (*D&O* at 50-51):

the Commission did three things:

First, the Commission explicitly recognized that Rule 14H provided a reliability standard for determining whether the addition of a given amount of as-available renewable energy to the grid of an island or region would compromise the reliability of the utility's electric system.

Second, the Commission implicitly acknowledged that the initial 5% system cap was based on a guess.

Third, the Commission deferred, until the "Reliability Standard" phase of the proceeding, the obtaining of an answer to Question 1 – to determine how much as-available renewable energy ***could*** be added to the grid of each island without compromising reliability -- and an answer to Question 2 -- to determine how much of the as-available renewable energy that could be added to the grid of each island without compromising reliability ***should*** be added and purchased by the utility based on the relative costs of the as-available renewable energy and any dispatchable non-renewable energy displaced by the as-available renewable energy.

II. THE CEM/ZEL RELIABILITY STANDARD COMPLIES WITH THE SEPTEMBER 25, 2009 DECISION & ORDER.

In response to the Commission's directions at pp. 50-51 of the *D&O*, Clean Energy Maui and Zero Emissions proposed the CEM/ZEL Reliability Standards, at Appendix III to the CEM/ZEL Schedule FIT, having two parts: "Technical Requirements for Interconnection" and "Reliability Standard for Curtailment."

The CEM/ZEL "Technical Requirements for Interconnection" re-iterate the Hawaiian Electric Companies' own technical requirements for interconnection of distributed generating facilities in Rule 14H. The CEM/ZEL "Technical Requirements for Interconnection" have the same purpose as the technical requirements under Rule 14H: "To maintain the reliability of the utility system for all utility customers." The CEM/ZEL "Technical Requirements for Interconnection," like the Hawaiian Electric Companies' own reliability standards in Rule 14H, provide an adequate technical basis for determining whether the addition of a given amount of as-available renewable energy to the grid of each island would compromise the reliability of the utility electric system, and, therefore, determining an answer to Question 1.

The purpose of the CEM/ZEL "Reliability Standard for Curtailment" is to specify a cap on the amount of as-available renewable energy that the utility ***should*** be obliged to purchase under a FIT, *i.e.*, an answer to Question 2, based on the utility's answer to Question 1, *i.e.*, how much as-available renewable energy ***could*** be added to the grid of each island without compromising electric system reliability based on the regulating capacity of the utility's must-run and dispatchable non-renewable generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation.

To "fill-in-the-blanks" of the CEM/ZEL "Reliability Standard for Curtailment", and find out how much as-available renewable energy ***could*** be added to the grid of each island without compromising electric system reliability based on the regulating capacity of the utility's must-run and dispatchable non-renewable generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation, Zero Emissions submitted ZE-IR-107 to the Hawaiian Electric Companies.

As with PUC-IR-1, the Hawaiian Electric Companies declined, in their responses to ZE-IR-107, to define how much renewable energy each island could incorporate. The HECO and the HELCO responses to ZE-IR-107(c) contain no kilowatt-hour figures at all. The MECO response to ZE-IR-107(c) contains no kilowatt-hour figures for potential curtailment of non-renewable energy generating facilities, and contains no kilowatt-hour figures for actual curtailment of renewable or non-renewable energy generating facilities. The Hawaiian Electric Companies' responses to ZE-IR-107(d) contain no kilowatt-hour figures at all.

As a result of the Hawaiian Electric Companies' refusal to answer Question 1 (as posed to the Hawaiian Electric Companies in the form of ZE-IR-107), Zero Emissions moved to compel the Hawaiian Electric Companies to provide responses to ZE-IR-107(c) and ZE-IR-107(d) in *Motion of Zero Emissions Leasing LLC to Compel Hawaiian Electric Companies to Provide Responses to Information Request*, filed March 8, 2010 (the "Motion to Compel"). In its *Memorandum* in support of the Motion to Compel, Zero Emissions argued:

> The Hawaiian Electric Companies' excuses for not providing the requested kilowatt-hour figures do not wash. The Hawaiian Electric Companies know or can reasonably estimate the kilowatt-hours of reduced generation from their dispatchable non-renewable generation when they cycle that generation up and down during a typical 24-hour load cycle. The Hawaiian Electric Companies know or can reasonably estimate how many kilowatt-hours they currently are receiving from as-available renewable generation during a typical 24-hour load cycle, how many hours that as-available renewable generation is being curtailed during a typical 24-hour load cycle, and how many kilowatt-hours of electricity from as-available renewable generation are currently being curtailed during a typical 24-hour load cycle. The Hawaiian Electric Companies know or can reasonably estimate capacity factors of as-available renewable energy generation for displacing dispatchable non-renewable generation with as-available renewable generation. The Hawaiian Electric Companies know the regulating capacity of their must-run and dispatchable non-renewable generation. The Hawaiian Electric Companies can reasonably estimate how much as-available renewable energy ***could*** be added to the grid of each island without compromising electric system reliability based on the regulating capacity of the utility's must-run and dispatchable non-renewable generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation.
>
> Zero Emissions believes that the Hawaiian Electric Companies do not want to answer ZE-IR-107(c) and (d) because they do not want to admit that there is a positive, substantial and reasonably ascertainable amount of as-available renewable energy that ***could*** be added to the grid of each island without compromising electric system reliability based on the regulating capacity of the utility's must-run and dispatchable non-renewable generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation.

In the HECO Companies' *Memorandum in Opposition to Motion of Zero Emissions Leasing LLC to Compel Hawaiian Electric Companies to Provide Responses to Information Requests*, filed March 15, 2010 (the "HECO Opposition Memo"), the HECO Companies do not deny that model inputs -- such as the number of kilowatt-hours of reduced generation from their dispatchable non-renewable generation when they cycle that generation up and down during a typical 24-hour load cycle, the number kilowatt-hours they currently are receiving from as-available renewable generation during a typical 24-hour load cycle, the number of hours that as-available renewable generation is being curtailed during a typical 24-hour load cycle, the number of kilowatt-hours of electricity from as-available renewable generation that are currently being curtailed during a typical 24-hour load cycle, the capacity factors of as-available renewable energy generation for displacing dispatchable non-renewable generation with as-available renewable generation and the regulating capacity of their must-run and dispatchable non-renewable generation -- cannot be reasonably estimated. In the HECO Opposition Memo, the HECO Companies do not deny that that there is a positive, substantial and reasonably ascertainable amount of as-available renewable energy that ***could*** be added to the grid of each island without compromising electric system reliability based on the regulating capacity of the utility's must-run and dispatchable non-renewable generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation.

Question 1 (in the form of ZE-IR-107) is answerable by the HECO Companies. The HECO Companies can answer Question 1 (in the form of ZE-IR-107) using the General Electric PSLF^{TM} "Transient Performance" electric system models that have been developed for the HECO Companies, using ratepayer and taxpayer funds, for the grids on each of the islands of Hawaii, Maui and Oahu,[2] and the "Simulink" electric system model

[2] *See* Terry Surles, "Status of Big Island, Maui and Oahu Projects," (Hawaii Natural Energy Institute October 19, 2009), accessed on March 20, 2010 at www.hnei.hawaii.edu/docs/publications/HCEI10192.ppt (the "HNEI Status Report") (attached as Attachment A hereto); GE Global Research and University of Hawaii "Maui Electrical System Simulation Model Validation," (U.S. Department of Energy November 2008) (the "Maui Model Report") (attached as Attachment B hereto); GE Global Research and University of Hawaii, "Summary Report on Stakeholder Workshop" (U.S. Department of Energy November 2007) (the "Hawaii Model Summary Report") (relevant portion attached as Attachment C hereto).

developed for the grid on the island of Lanai (the "Electric System Models").[3] The GE PSLF™ Transient Performance model simulates transient stability and long-term dynamic stability of the electric system, i.e., reliability, from the addition of as-available renewable energy such as wind.[4] The Simulink model, using an "eMEGASim" real-time simulator, simulates overall stability and transient responses, i.e., reliability, of the Lanai grid from the addition of intermittent photovoltaic distributed generation.[5] The Electric System Models have been validated for the grids of the islands of Hawaii, Maui, Oahu and Lanai.[6]

The very purpose of the Electric System Models is to answer Question 1. Terry Surles of Hawaii Natural Energy Institute states that these models are, "Sufficiently accurate to provide reasonable comparisons of impacts on system metrics due to technology, policy or operational choices," and that their "Results can be used by informed analysts, not requiring detailed power system engineering."[7] Question 1 is answerable by the HECO Companies using the Electric System Models.

In the HECO Opposition Memo, the HECO Companies assert:

> … Hawaiian Electric is not able to provide the amounts by which energy can be curtailed during a 24 hour period …

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[3] *See* "Sandia National Laboratories uses Real-Time Simulation to Shed Light on the use of Photovoltaic Distributed Generation in Hawaii," (Opal RT Technologies "Planet-RT" December 2009), accessed on March 20, 2010 at http://www.opal-rt.com/success-story/sandia-national-laboratories-uses-real-time-simulation-shed-light-use-photovoltaic (the "Lanai Model Report") (attached as Attachment D hereto).
[4] HNEI Status Report at 8, 10.
[5] Lanai Model Report.
[6] *See* HNEI Status Report at 25 (Oahu "Models have been developed, validated and reviewed by [Technical Review Committee] made up of national and international experts"); Maui Model Report at 1 ("The modeling, validation and management team is comfortable with the level of accuracy for … the GE PSLF™ … [model] of the MECO system for the application of these tools to system scenario analysis"); Hawaii Model Report at Appendix B ("Models have been calibrated and validated against historical data to the high degree of accuracy required to meet project objectives"); Lanai Model Report ("… using physical hardware … Sandia conducted extensive testing … to determine whether the positive results received with the Simulink/SimPowerSystems models remained accurate. … Preliminary results for generator transient responses and PV output have been positive.")
[7] HNEI Status Report at 9.

> … there is no single number that could be provided in response to this information that would be accurate …
>
> … any attempt at a precise response would also be speculative …
>
> … basing any decision to add one type of resource based on an assumed level of curtailment of another type of resource would be speculative and inconsistent with preserving the reliability of the utility electric system. Similarly, the use of historical system information without consideration of reasonably anticipated system additions or operational conditions, is also inconsistent with a meaningful assessment of system reliability …

The HECO Companies' assertions that answers to Question 1 (in the form of ZE-IR-107) would be "speculative" and "inconsistent with a meaningful assessment of system reliability" is to deny the very existence and validity of the Electric System Models that the HECO Companies themselves have developed and validated for the grids on each of the islands of Hawaii, Maui, Oahu, and Lanai. The HECO Companies' assertion that Question 1 is unanswerable because any answer would be "speculative" and "inconsistent with a meaningful assessment of system reliability" is false because the HECO Companies possess validated Electric System Models, and either know or can reasonably estimate the model inputs, needed to produce meaningful and non-speculative answers to Question 1 that are "Sufficiently accurate to provide reasonable comparisons of impacts on system metrics due to technology, policy or operational choices."

III. ZERO EMISSIONS SUPPORTS OPENING OF A NEW DOCKET TO INVESTIGATE ESTABLISHMENT OF THE BPF RELIABILITY STANDARDS.

In its filing submitted on February 8, 2010, Blue Planet Foundation proposed formal bulk electric system reliability standards governing the Hawaiian Electric Companies' electric systems ("Hawaii NERC RS") that would be (i) equivalent to the formal bulk electric system reliability standards ("NERC RS") administered by the North

American Electric Reliability Corporation ("NERC"), (ii) developed in the future pursuant to a future stakeholder-driven process, overseen by an independent entity, and (iii) upon completion, administered by an independent entity, such as a Hawaii Independent System Operator ("HISO"). The NERC RS can be found on-line at http://www.nerc.com/files/Reliability_Standards_Complete_Set_2010Jan25.pdf where they run 1074 pages.

Zero Emissions joins in and supports adoption of a Hawaii NERC RS based on NERC RS. Zero Emissions believes, however, that adoption of a set of reliability standards running to 1074 pages and governing interconnection of all generating facilities to the electric systems of the HECO Companies is a task that is likely to take at least 2 years and justifies the opening of a separate investigatory docket by the Commission.

Zero Emissions believes that it is not necessary to wait 2 years or more for the implementation of reliability standards based on NERC RS before getting an answer to Question 1 and so proceeding with implementation of a genuine feed-in tariff, such as the CEM/ZEL proposed Schedule FIT, that obliges the HECO Companies to purchase as-available renewable energy up to an amount that does not compromise electric system reliability (based on the answer to Question 1) and that makes economic sense (based on the answer to Question 2). The HECO Companies' own reliability standards in Rule 14H provide an adequate technical basis for determining whether the addition of a given amount of as-available renewable energy to the grid of each island would compromise the reliability of the utility electric system, for purposes of answering Question 1. The HECO Companies possess the electric system models, and know or can reasonably estimate the quantitative inputs for such models, to reasonably estimate how much as-available renewable energy ***could*** be added to the grid of each island without compromising electric system reliability based on the regulating capacity of the utility's must-run and dispatchable non-renewable generation, taking into account any displacement of the utility's dispatchable non-renewable generation by the added as-available renewable energy generation.

IV. THE HECO RS REPORT AND THE HECO RSWG PROPOSAL ARE BUILT ON THE FALSEHOOD THAT QUESTION 1 IS UNANSWERABLE

Instead of proposing a true set of "reliability standards," like Rule 14H (as re-iterated in the CEM/ZEL Reliability Standards) or NERC RS (as proposed in the BPF Reliability Standards), that would provide an objective basis for determining whether addition of a given amount of as-available renewable energy would compromise reliability of the utility electric system and, therefore, that would provide an objective basis for answering Question 1, the HECO Companies (1) filed a "Report" that proposed a 0 MW cap on the amount of as-available renewable energy that the utility might purchase on the islands of Hawaii, Maui, Molokai and Lanai, and a 60 MW cap on the amount of as-available renewable energy that the utility might purchase on the island of Oahu, and (2) proposed convening of a "Reliability Standards Working Group," redundant to the utilities' Integrated Resource Planning processes, in which the FIT docket intervenors would have no procedural rights to obtain answers to Question 1 from the HECO Companies, and in which the HECO Companies would never have to answer Question 1.

Basically, the HECO Companies are falsely implying, in the HECO RS Report and the HECO RSWG Proposal, that Question 1 is unanswerable and that, therefore, the

Commission should ***assume*** that the answer to Question 1 is 0 MW for the islands of Hawaii, Maui, Molokai and Lanai (and 60 MW for Oahu), until completion of a "Reliability Standard Working Group" process in which the HECO Companies would not be committed or obliged to answer Question 1.

The purpose of the HECO Companies' proposals in the HECO RS Report and the HECO RSWG Proposal is to evade answering Question 1 and so avoid establishment of a FIT that results in any displacement of any dispatchable non-renewable generation by as-available renewable generation.

A. THE HECO RS REPORT AND THE HECO RSWG PROPOSAL FALSELY IMPLY THAT QUESTION 1 IS UNANSWERABLE BY CONCEALING THE EXISTENCE OF THE VALIDATED ELECTRIC SYSTEM MODELS AND BY CONCEALING ANY QUANTITATIVE RESULTS THAT COULD BE OBTAINED FROM THE VALIDATED ELECTRIC SYSTEM MODELS.

The HECO RS Report and the HECO RSWG Proposal falsely imply that Question 1 is unanswerable by concealing the existence of the validated Electric System Models,[8] and by concealing any quantitative results that could be obtained from the validated Electric System Models.[9] The HECO RS Report and the HECO RSWG

[8] The "HECO Distribution System Analysis" at pp. 13 and 19 of Attachment 1 to the HECO RS Report mentions the GE PSFL software, but does not mention the existence of the validated GE PSFL electric system model for the island of Oahu and does not present any quantitative results obtained from the validated GE PSFL electric system model for the island of Oahu.

[9] The "Evaluation of Distributed Generation" at Attachment 2 to the HECO RS Report, the "Evaluation of System Balancing and Frequency Control" at Attachment 3 to the HECO RS Report, and the "Evaluation of HELCO and MECO Excess Energy and Curtailment" at Attachment 4 to the HECO RS Report do not mention the existence of the validated GE PSFL electric system model for the island of Hawaii and do not present any quantitative results obtained from the validated GE PSFL electric system model for the island of Hawaii. The "Evaluation of System Balancing and Frequency Control" at Attachment 3 to the HECO RS Report and the "Evaluation of HELCO and MECO Excess Energy and Curtailment" at Attachment 4 to the HECO RS Report do not mention the existence of the validated GE PSFL electric system model for the island of Maui and do not present any quantitative results obtained from the validated GE PSFL electric system model for the island of Maui. The "Lanai Analysis" at Attachment 5 to the HECO RS Report does not mention the existence of the validated Simulink electric system model for the island of Lanai and does not present any quantitative results obtained from the validated Simulink electric system model for the island of Lanai.

Proposal make no mention of the existence of the validated Electric System Models. The HECO RS Report and the HECO RSWG Proposal contain no quantitative evidence -- of the effects on electric system reliability from the addition of a given amount of as-available renewable energy -- that could be obtained from the validated Electric System Models.

The HECO Companies omitted any mention of the existence of the validated Electric System Models, and omitted any quantitative results that could have been obtained from the Electric System Models, because the HECO Companies do not want the Commission to know that the validated Electric System Models exist, that the HECO Companies could use the validated Electric System Models to answer Question 1, and that Question 1 is answerable. The HECO Companies are concealing, from the Commission, the existence of the validated Electric System Models, and are concealing, from the Commission, any quantitative results that could have been obtained from the Electric System Models, because the HECO Companies do not want the Commission to know that there is a there is a positive, substantial and reasonably ascertainable amount of as-available renewable energy that could be added to the grids on Hawaii, Maui, Molokai, Lanai and Oahu, and a reasonably ascertainable amount of dispatchable non-renewable energy that could be displaced by such added as-available renewable energy, without compromising reliability.

By misleadingly omitting any mention of the validated Electric System Models and misleadingly omitting any quantitative results that could be obtained from the validated Electric System Models, the HECO Companies would have the Commission believe that Question 1 is unanswerable. Question 1 is unanswered, not because it is unanswerable, but because the HECO Companies have the validated Electric System Models and refuse to use them to answer Question 1.

B. INSTEAD OF TRUTHFULLY ANSWERING QUESTION 1 USING THE VALIDATED ELECTRIC SYSTEM MODELS, THE HECO COMPANIES FALSELY IMPLY THAT QUESTION 1 IS NOT ANSWERABLE FOR OAHU AND FALSELY ASSERT THAT THE ANSWER TO QUESTION 1 IS 0 MW FOR HAWAII, MAUI, MOLOKAI AND LANAI.

1. INSTEAD OF USING THE VALIDATED ELECTRIC SYSTEM MODEL TO TRUTHFULLY ANSWER QUESTION 1 FOR OAHU, THE HECO COMPANIES FALSELY IMPLY THAT QUESTION 1 IS NOT ANSWERABLE.

Instead of using the Electric System Model that has "been developed, validated and reviewed by [Technical Review Committee] made up of national and international experts" to truthfully answer Question 1 now for Oahu,[10] the HECO Companies falsely imply that Question 1 is unanswerable now for Oahu by falsely stating that an answer to Question 1 will require "additional more refined studies ... over the course of the next year, in time to support the next FIT Reliability Standards update."[11] It can be inferred from the HECO Companies' concealment of the validated Electric System model for Oahu, and the HECO Companies' concealment of any quantitative results from the validated Electric System Model for Oahu, that the answer to Question 1, ascertainable now using the validated Electric System Model for Oahu, is substantially more than the 60 MW figure, which the HECO Companies are willing to admit is a lower limit on the answer to Question 1.

The HECO Companies' proposed 60 MW cap on the amount of as-available renewable energy that should be added to the Oahu grid is merely the product of the

[10] HNEI Status Report at 25.

Oahu peak demand and the 5% initial system cap, which the Commission implicitly acknowledged was based on a guess. The proposed 60 MW cap is just a guess because it was not obtained from the validated Electric System Model for Oahu. The "HECO System Distribution Analysis," at Attachment 1 to the HECO RS Report, contains no information about the assumptions or inputs for the model used in that analysis, and contains no evidence that the model used in that analysis was validated for the Oahu grid, or that it was capable of yielding an accurate answer to Question 1.

In 2007, HECO issued a *Solicitation of Interest for Non-Firm Renewable Energy Projects: Island of Oahu* (the "2007 HECO RFP") that requested proposals for 100 MW of as-available renewable generation on Oahu. HECO must have believed, based on its own internal electric system modeling, that the answer to Question 1 was at least 100 MW for Oahu when it released the 2007 HECO RFP. HECO's issuance of the 2007 HECO RFP shows that Question 1 was answerable in 2007 using whatever internal electric system model HECO had in 2007. If Question 1 was answerable in 2007 for Oahu, it must be answerable now for Oahu, not "next year, in time to support the next FIT Reliability Standards update."

2. INSTEAD OF USING THE VALIDATED ELECTRIC SYSTEM MODEL TO TRUTHFULLY ANSWER QUESTION 1 FOR THE ISLANDS OF HAWAII AND MAUI, THE HECO COMPANIES FALSELY ASSERT THAT THE ANSWER TO QUESTION 1 IS 0 MW FOR THE ISLANDS OF HAWAII AND MAUI.

Instead of using the validated Electric System Model to truthfully answer Question 1 for the islands of Hawaii and Maui, the HECO Companies falsely assert that

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[11] Ron Davis, "HECO System Distribution Analysis," Attachment 1 to HECO RS Report at p.2.

the answer to Question 1 is 0 MW for the islands of Hawaii and Maui[12] by falsely and misleadingly asserting that the utility would ***choose*** to reduce the regulating capacity of the utility's entire dispatchable non-renewable generation to zero with the addition of any as-available renewable energy to the grid for the islands of Hawaii and Maui. In Attachment 4 to the HECO RS Report, the HECO Companies falsely and misleadingly assert that the utility would ***choose*** to reduce the utility's entire dispatchable non-renewable generation to its "minimum" level, and thus minimize the regulating capacity available from such dispatchable non-renewable generation, with the addition of any as-available renewable energy to the grid for the island of Hawaii.[13] Basically, the HECO

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[12] The HECO Companies assert, at p. 4 of the HECO RS Report:

> ... Due primarily to the high level of existing and planned renewable resource penetration on the MECO and HELCO systems, the studies indicate that there is minimal to no room at this time to accommodate additional renewable resources (FIT or otherwise) without significant curtailment of either existing or planned renewable resources, or a threat to system reliability. ...

[13] The HECO Companies assert in Attachment 4 to the HECO RS Report ("HECO RS Att. 4"):

> **There is a potential reliability risk operating near minimum output on dispatchable units.** The minimum dispatchable output for each dispatchable unit is determined by the lowest level of stable operation on the generating unit. Operating below this level can result in the unit tripping offline or cause deviations from environmental permit requirements. When all units are near the minimum output, the system is vulnerable to failure for loss-of-load events. The ability of the units to back down for high frequency excursions is limited and the units may be driven offline. The present regulating reserve down requirement has been set at the minimum regulating reserve down for the single contingency loss of load during minimum load (off-peak) conditions. Loss of more than this amount (6 MW on the MECO system, 9 MW on the HELCO system) can drive the responsive units (through their droop response) to below their stable operating point and risk loss of the units, or prolonged high-frequency excursions which may cause trips of other generation and cascading outages. The potential loss of load is larger during daytime conditions ... (*HECO RS Att. 4* at 6) [emphasis added]
>
> ...during high variable output, in the absence of significant load growth the HELCO system cannot accommodate all future and existing RE **even if all dispatchable conventional generation operates nearly twenty four hours at near minimum output**. As mentioned above, operating in that manner ... may not be prudent due to potential reliability implications. (*HECO RS Att. 4* at 8) [emphasis added]
>
> ... Similar to HELCO, absent significant load growth, MECO cannot accommodate all the existing or future renewable generation **even with conventional generation backed down to minimum (plus down reserve) 24 hours a day**. (*HECO RS Att. 4* at 9). [emphasis added]

Companies are saying that the amount of as-available renewable energy that could be added to the grids on Hawaii and Maui without compromising reliability is 0 MW because the utility would ***intentionally choose*** to compromise reliability by reducing its entire dispatchable non-renewable generation to zero, and thereby reducing to zero the amount of regulating capacity available from such dispatchable non-renewable generation to maintain reliability with the addition of any as-available renewable energy.

The HECO Companies assert that electric system reliability will be compromised on the island of Hawaii by the addition of as-available renewable energy "**even if** all dispatchable conventional generation operates nearly twenty four hours a day at near minimum output,"[14] and will be compromised on the island of Maui by the addition of as-available renewable energy "**even with** conventional generation backed down to minimum (plus down reserve) 24 hours a day."[15] [emphasis added] The HECO Companies use the expressions "even if" and "even with" to falsely and misleadingly imply that the utility's choice to reduce its entire dispatchable non-renewable generation to its "minimum" would help maintain system reliability. The truth is that the utility's choice to reduce its dispatchable non-renewable generation to its minimum would ***compromise*** reliability by reducing to zero the regulating capacity from such generation.

The HECO RS Report frames the addition of as-available renewable energy to the grids on Hawaii and Maui as a false "either/or" proposition: either the added as-available

---

> **The HELCO system will operate under extended periods with a minimal amount of dispatchable generation online.** This will have an effect on ... the response capabilities for frequency control. MECO has similar concerns and must make additional decisions regarding minimum conventional generation, to cover for variability, as unlike HELCO the renewable energy additions are all variable. (*HECO RS Att. 4* at 16) [emphasis added]

[14] HECO RS Report at 17.
[15] HECO RS Report at 23.

renewable generation and existing renewable generation is curtailed to maintain system reliability, or the utility compromises system reliability by taking delivery of the added as-available renewable energy and reducing its entire dispatchable non-renewable generation to zero. The HECO Companies' false proposition excludes the possibility -- which would be revealed by a truthful answer to Question 1 using the validated Electric System Models for the islands of Hawaii and Maui – that there exists some amount of as-available renewable energy that could be added to the grid of each island, and some amount of dispatchable non-renewable energy that could be displaced by such added as-available renewable energy, without compromising electric system reliability and without the need to convene a Reliability Standards Working Group to determine those amounts.

The "Load Duration" curves shown in the HECO RS Report falsely state the number of hours of curtailment needed to maintain system reliability because they are calculated based on the false assumption that the utility has chosen to intentionally compromise system reliability by reducing the utility's dispatchable non-renewable generation, and the regulating capacity available from the utility's dispatchable non-renewable generation for maintaining system reliability, to zero.

It can be inferred from the HECO Companies' concealment of the validated Electric System models for Hawaii and Maui, and the HECO Companies' concealment of any quantitative results from the validated Electric System Models for Hawaii and Maui, that the answer to Question 1, ascertainable now using the validated Electric System Models for Hawaii and Maui, is substantially more than the HECO Companies' proposed 0 MW cap on the amount of as-available renewable energy that should be added to the grids on the islands of Hawaii and Maui.

The HECO Companies' proposed 0 MW cap on the amount of as-available renewable energy that should be added to the Hawaii and Maui grids is just a guess because it was not obtained from the validated Electric System Models for the islands of Hawaii and Maui. The "Evaluation of Excess Energy and Curtailment," at Attachment 4 to the HECO RS Report, contains no information about the model used in that evaluation, contains almost no information about the assumptions or inputs for the model used in that evaluation (except the assumption that the utility would zero out its dispatchable non-renewable generation and the regulating capacity from that generation available to maintain reliability), contains no evidence that the model used in that evaluation was validated for the Hawaii or Maui grids, and contains no evidence that the model used in that evaluation was capable of yielding an accurate answer to Question 1.

If the HECO Companies' assertions were true – that the answer to Question 1 is 0 MW for the islands of Hawaii and Maui – then the HECO Companies would not have to conceal the existence of the validated Electric System Models for Hawaii and Maui and any quantitative results obtained from the validated Electric System Models for Hawaii and Maui, would not have to falsely and misleadingly assert that the utility would ***choose*** to reduce the regulating capacity of the utility's entire dispatchable non-renewable generation to zero with the addition of any as-available renewable energy to the grid for the islands of Hawaii and Maui, and would reveal the models, assumptions and inputs actually used for the "Evaluation of Excess Energy and Curtailment" at Attachment 4 to the HECO RS Report.

3. INSTEAD OF USING THE VALIDATED ELECTRIC SYSTEM MODEL TO TRUTHFULLY ANSWER QUESTION 1 FOR LANAI, THE HECO COMPANIES FALSELY IMPLY THAT THE ANSWER TO QUESTION 1 IS 0 MW FOR LANAI.

Instead of using the validated Electric System Model to truthfully answer Question 1 for Lanai, the HECO Companies falsely imply – in proposing a 0 MW cap on additions of as-available renewable energy to the Lanai grid -- that the answer to Question 1 is 0 MW for Lanai. It can be inferred from the HECO Companies' concealment of the validated Electric System model for Lanai, and the HECO Companies' concealment of any quantitative results from the validated Electric System Models for Lanai, that the answer to Question 1, ascertainable now using the validated Electric System Model for Lanai, is substantially more than the HECO Companies' proposed 0 MW cap on the amount of as-available renewable energy that should be added to the grid on the island of Lanai.

The HECO Companies' proposed 0 MW cap on the amount of as-available renewable energy that should be added to the Lanai grid is just a guess because it was not obtained from the validated Electric System Model for the island of Lanai. The "Lanai Analysis," at Attachment 5 to the HECO RS Report, contains no information about any model used in that analysis, contains no information about any assumptions or inputs for any model used in that analysis, contains no evidence that any model used in that analysis was validated for the Lanai grid, and contains no evidence that any model used in that analysis was capable of yielding an accurate answer to Question 1.

4. INSTEAD OF TRUTHFULLY ANSWERING QUESTION 1 FOR MOLOKAI, THE HECO COMPANIES FALSELY IMPLY THAT THE ANSWER TO QUESTION 1 IS 0 MW FOR MOLOKAI.

It may be inferred from the HECO Companies' concealment of the validated Electric System Models for Oahu, Hawaii, Maui and Lanai, that the HECO Companies are also concealing the existence of a validated electric system model for the island of Molokai.[16] Instead of using a validated electric system model to truthfully answer Question 1 for Molokai, the HECO Companies falsely imply -- in proposing a 0 MW cap on additions of as-available renewable energy to the Molokai grid -- that the answer to Question 1 is 0 MW for Molokai. It can be inferred from the HECO Companies' concealment of a validated electric system model for Molokai, and the HECO Companies' concealment of any quantitative results from such a model, that the answer to Question 1, ascertainable using such a model, is substantially more than the HECO Companies' proposed 0 MW cap on the amount of as-available renewable energy that should be added to the grid on the island of Molokai.

The HECO Companies' proposed 0 MW cap on the amount of as-available renewable energy that should be added to the Molokai grid is just a guess because it was not obtained from a validated electric system model for the island of Molokai. The "Molokai Analysis," at Attachment 6 to the HECO RS Report, contains no information about any model used in that analysis, contains no information about any assumptions or inputs for any model used in that analysis, contains no evidence that any model used in that analysis was validated for the Molokai grid, and contains no evidence that any model used in that analysis was capable of yielding an accurate answer to Question 1.

V. <u>THE COMMISSION NEEDS TRUTHFUL ANSWERS TO QUESTION 1.</u>

To advance a genuine FIT and the other renewable energy policy initiatives contained in the Hawaii Clean Energy Agreement, the Commission needs truthful

[16] The Lanai Model Report states, "We also take the utility's model, put it into Simulink and go to our lab." It can be inferred that since the HECO Companies have their own electric system model for Lanai, pre-existing the validated Simulink Electric System Model for Lanai, then the HECO Companies also possess their own electric system model for Molokai.

answers to Question 1, not a "Reliability Standards Working Group" designed to evade an answer to Question 1. The Commission can get a truthful answer to Question 1 in at least 3 different ways:

(1) The Commission could grant Zero Emissions' Motion to Compel the HECO Companies to answer ZE-IR-107;

(2) The Commission, acting *sua sponte*, could order the HECO Companies, to answer Question 1, in the form of PUC-IR-101 or any other form that the Commission thinks proper;

(3) The Commission could appoint a qualified independent expert, such as National Renewable Energy Laboratory, to investigate the HECO Companies' electric systems and use the Electric System Models to answer Question 1.

An answer to Question 1 is needed as a first step to determining how much as-available renewable energy the utilities ***should*** be obliged to purchase under a FIT. A truthful answer to Question 1 would make unnecessary a Reliability Standards Working Group in this docket.

Establishing the "Reliability Standards Working Group" proposed by the HECO Companies and not obtaining an honest answer to Question 1 would be to delay by years, if not forever, implementation of a genuine feed-in tariff, like the CEM/ZEL Schedule FIT, designed "to dramatically accelerate the addition of renewable energy from new sources." The longer the HECO Companies are allowed to evade answering Question 1, the greater will be the costs and risks to the public of delaying Hawaii's transition to renewable energy and perpetuating Hawaii's dependence on imported oil.

VI. HECO COMPANIES ARE NOW PROPOSING A 60 MW REQUEST FOR PROPOSALS FOR OAHU, NOT A FEED-IN TARIFF.

The HECO Companies' proposed "Tier 1 and Tier 2 Tariff" is a request for proposals, not a feed-in tariff, because the HECO Companies' proposed "Tier 1 and Tier 2 Tariff" lacks the 2 elements – a guarantee of payments to project owners for total kWh of renewable electricity produced and a guarantee of access to the grid – that create the quantity certainty and, therefore, the revenue certainty that project developers need to obtain financing for their renewable energy projects. The HECO Companies' proposed "Tier 1 and Tier 2 Tariff" is a sham feed-in tariff because under it, the HECO Companies would have no obligation to interconnect a single kW of renewable energy generation (even if reliability requirements such as Rule 14H are met), and would have no obligation to purchase a single kWh of renewable energy. Under the HECO Companies' proposed Tier 1 and Tier 2 Tariff, the utility would be free to pick and choose what renewable generation, if any, would be interconnected with the grid, and would be free to pick and choose (and curtail) the amount of renewable energy, if any, that the utility would purchase, just as it would under a request for proposals.

With the HECO HS Report's proposal of a 0 MW cap on the amount of as-available renewable energy that the utility ***might*** purchase on the islands of Hawaii, Maui, Molokai and Lanai, and a 60 MW cap on the amount of as-available renewable energy that the utility ***might*** purchase on the island of Oahu, the HECO Companies' proposed Tier 1 and Tier 2 Tariff is now essentially a scaled-down version of HECO's 2007 *Solicitation of Interest for Non-Firm Renewable Energy Projects: Island of Oahu* (the "2007 HECO RFP") that requested proposals for 100 MW of as-available renewable generation on Oahu. Zero Emissions is not aware of a single kW of renewable generation that has been placed in service on the Oahu grid as a result of the 2007 HECO RFP. If the Commission approves the HECO Companies' proposed Tier 1 and Tier 2 Tariff during 2010, the result will have been 3 years of wasted time to come up with a Commission-approved request for proposals that is not materially different from the 2007 HECO RFP except that it is ***smaller*** than the 2007 HECO RFP by 40 MW. The HECO Companies' proposed Tier 1 and Tier 2 Tariff would take Hawaii ***backwards***, to 2007 to be exact, by foreclosing adoption of a genuine feed-in tariff, like the CEM/ZEL Schedule FIT, that actually would "'... dramatically accelerate the addition of renewable energy from new sources' and ...'encourage increased development of alternative energy projects.'" *D&O at 13.*

* * * *

DATED: Honolulu, Hawaii, March 23, 2010

Erik Kvam
Chief Executive Officer
Zero Emissions Leasing LLC

Attachment A

Status of Big Island, Maui, and Oahu Projects

HCEI Plenary Session

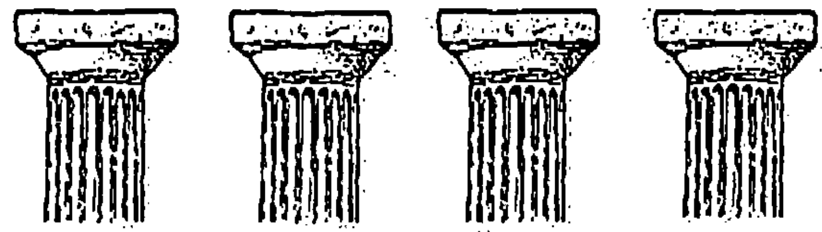
Terry Surles

Hawaii Natural Energy Institute

October 19, 2009

Partnerships Are Critical For Addressing Overarching Issues Facing Electricity Systems

Electricity System Issues



Grid Modernization: Renewable Technologies Peak Demand

Global Climate Change

Energy Security: Fuel Supplies, Critical Infrastructure Protection

Environment Quality: Life cycle analyses

None Of These Issues Can Be Resolved Without Partnerships

Partnerships Require Understanding and Can Be Difficult!!

Hawaii Energy Resource Technologies for Energy Security

- US DOE funded program since FY06 to develop, demonstrate, and deploy technologies to facilitate greater penetration of Hawaii's renewable resources into its energy systems
- HNEI-led partnership with DBEDT and industry (General Electric, HECO/HELCO/MECO, Sentech), as part of a larger partnership with New Mexico Tech
- Transportation (Big Island) and electricity systems models have been developed for the Big Island, Maui, and (currently) Oahu
- Results are intended to address key national issues: grid modernization, energy security, and climate change
- As of FY10, this is now known as the Hawaii Sustainable Energy Program

Program is Unique in Being Able to Address Needs of Four Different End-Users plus the Stakeholders

•**Meet DOE mission needs – transferability of analytical tools**

- An understanding of the technical impact of renewable energy deployments as they relate to the mainland
- Lessons for mainland systems and analytical tools for mainland grids
- Mechanisms for addressing **stakeholder needs**

–**Address utility system planning needs – with accurate and usable tools**

- Mechanism for evaluating new technologies to address system impacts
- An understanding of impacts of renewable energy technology deployments

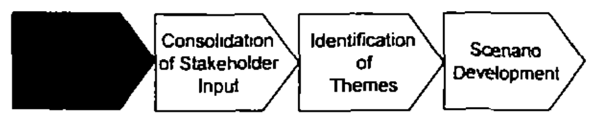
–**Address state (DBEDT and PUC) initiatives**

- A methodology and tool for State policymakers to analyze the impacts and tradeoffs of technologies (high penetration renewable energy) and policies (RPS).
- An in-state capability to perform further energy analyses – starting with the PUC

–**Provide information to commercialize clean energy products and respond to concerns of multiple business-environment-consumer stakeholders in Hawaii**

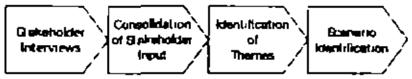
Stakeholder Interviews

- What are your key energy-related **metrics**?
- What are your **energy goals** for 2020?
- Is 2020 an appropriate **target** for the study?
- What do you see as **key global influences**?
- What do you see as key **energy technologies**?
- What **policies** should Hawaii implement?
- What other **energy issues** concern you?



County of Hawaii Energy Office
Bob Arrigoni
Economic Development Alliance of Hawaii
Paula Helfrich
Enterprise Honolulu
Mike Fitzgerald and John Strom
Fairmont Orchid
Ed Andrews
Hamakua Energy Partners
Joe Clarkson
Hawai'i County Council
Pete Hoffmann
Hawai'i Island Economic Development Board
Mark McGuffie
Hawaiian Electric Company, Ltd.
Karl Stahlkopf
Hawai'i Electric Light Company, Inc.
Hal Kamigaki, Chengwu Chen, Art Russell, Lisa Dangelmaier
Hawi Renewable Development
Jim Nestman, Raymond Kanehaikua
Hilton Waikoloa Village
Rudy Habelt (Director of Property Operations)
Kohala Center
Betsy Cleary-Cole (Deputy Director)
Life of the Land
Henry Curtis (Executive Director)
Office of Hawaiian Affairs
Mark Glick Yuko Chiba
Powerlight
Riley Saito
State of Hawaii, Department of Business, Economic Development & Tourism
John Tantlinger Steve Alber, Priscilla Thompson
State of Hawaii, Public Service Commission, Division of Consumer Advocacy
Catherine Awakuni
Tesoro Hawaii Corporation
Carlos De Almeida
University of Hawaii at Manoa
Makena Coffman

Scenarios Selected for Big Island Analysis



BASELINE

Based on a specific technology deployments outlined in the utility integrated resource plan.

HIGHER WIND PENETRATION

Expanding the presence of wind power and analyzing various strategies for addressing the challenges of intermittency.

REDUCED ENERGY VULNERABILITY

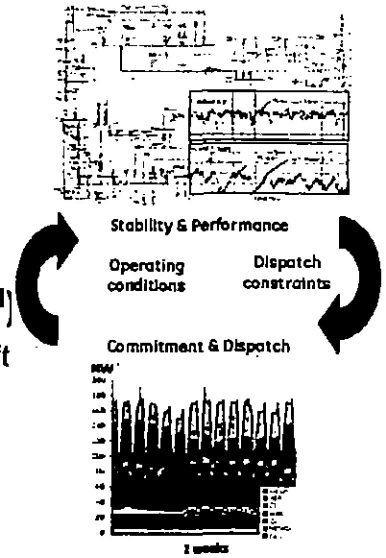
Increasing the penetration of more secure energy resources, primarily geothermal power.

ENHANCED ENERGY MANAGEMENT

Increasing the presence of energy efficiency and load control programs, PHEV vehicles, and use of combined heat and power.

Electricity Infrastructure Modeling

- **Transient Performance (PSLF™)**
  - Full network model, incorporating generator governors and AGC
  - Transient Stability Simulation
  - Long-Term Dynamic Simulation
- **Production Cost (MAPS™)**
  - Representation of dispatch and unit commitment rules
  - Hour-by-hour simulation of grid operations for a full year



The Effort Utilized Two Energy Roadmap Analytical Tools:

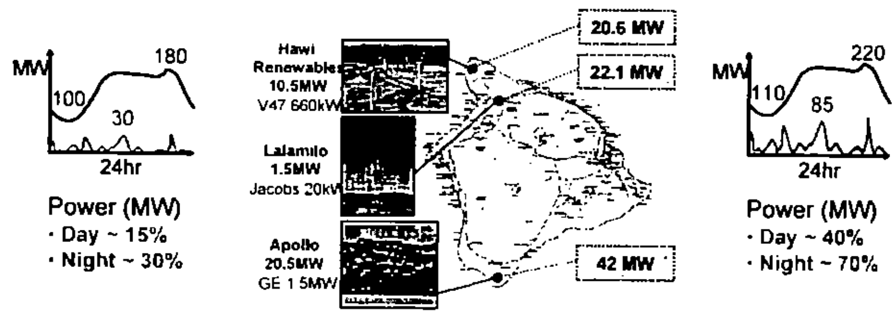
- **What They Are**
  - Technology neutral and objective
  - Sufficiently accurate to provide reasonable comparisons of impacts on system metrics due to technology, policy, or operational choices
  - Indicative of financial effects: who pays, who benefits - and by how much
  - Results can be used by informed analysts, not requiring detailed power system engineering
- **What They Are Not**
  - Not designed for utility operations, but for policy makers and senior management
  - Not configured for rigorous engineering requirements for planning and design
  - Not designed to replace IRP process
- **We are clear on the distinction between operations analysis and scenario analysis. These tools are designed for the latter.**

High Wind Penetration Scenario

Given interest in Hawaii for increased wind farm development, a renewable energy strategy consisting mainly of increased wind utilization was considered. **Wind capacity was increased at each of three wind farms on the Big Island.**

In 2007...

In 2018...

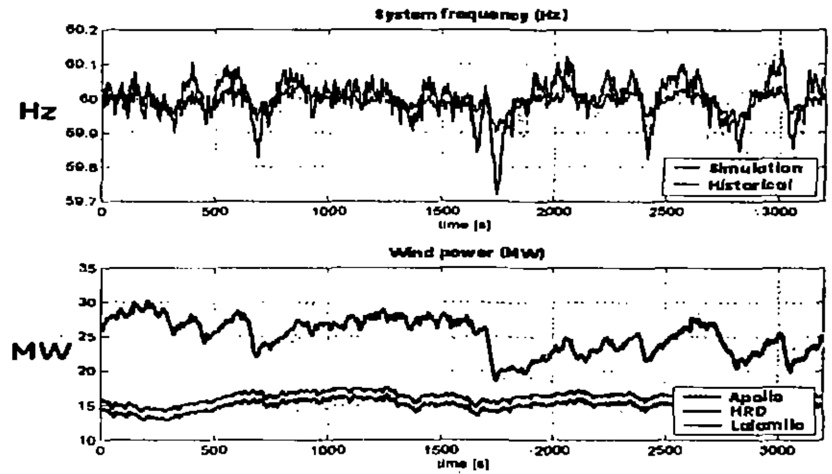


Fossil Fuel Consumption and Greenhouse Gas Emissions Decline in High Wind Penetration Scenario

HIGHER WIND PENETRATION - BASELINE

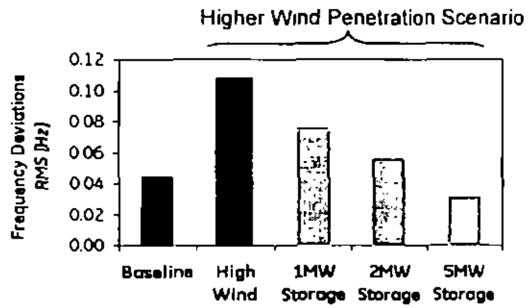
	Capacity MW	Energy GWh	Fuel MMBtu	NOx tons	SOx tons	CO2 tons
Combined Cycle	0	-124	-958546	-140	-144	-83340
Combustion Turbine	0	-31	-421448	-16	-54	-31423
Diesel	0	4	179	228	6	3468
Puna Geothermal	0	0	0	0	0	0
Small Hydro	*0*	*0*	*0*	*0*	*0*	*0*
Steam Oil	0	-31	-379130	-533	-61	-35521
Wind	52	189	0	0	0	0
% Change	16%	0%	-15%	-45%	-14%	-14%

System Performance Is Impacted in High Wind Penetration Scenario



Modeling the Efficacy of "Fast, Inter-Hour" Energy Storage

Models imply that a 5MW storage device reduces RMS to below that of the Baseline case



- **While these modeling results are encouraging, there is a need to validate model results with demonstrations!!!**

Enhanced Energy Management Scenario Examined Linkage Between Energy Sectors as well as Improved Energy Efficiency and DSM

<u>HELCO Energy Efficiency/DSM Programs</u>

Existing:
- Residential Efficient Water Heating Program (REWH),
- Commercial and Industrial Energy Efficiency Program (CIEE),
- Commercial and Industrial New Construction Program (CINC),
- Commercial and Industrial Customized Rebate Program (CICR),

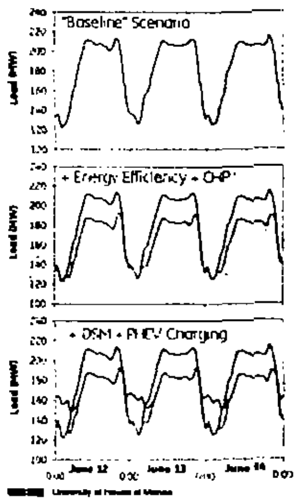
New:
- Energy Solution for the Home Program (ESH),
- Residential Qualifying Income Program (RQI),
- Residential New Construction Program (RNC),
- Residential Direct Load Control (RDLC),
- Commercial and Industrial Load Management (CILM).

<u>HELCO Programs</u>
Taken from current IRP

	Energy Efficiency Program	2018 Peak MW Reduction	2018 GWh Reduction
Existing	REWH	2.4	8.5
	CIEE	3.7	25.6
	CINC	2.3	18.2
	CICR	3.2	16.6
New	ESH	1.9	5.7
	RQI	0.3	1.7
	RNC	1.7	5.0
Load Control	RDLC	2.7	0.0
	CILM	2.4	0.0
Rates	RTOU	0.3	0.0
	Sum	20.9	81.3

Enhanced Energy Management Scenario

- The peak load reduction was obtained from HELCO's most recent IRP.
- PPAs: IPP price scaled by ratio of forecasted 2018 fuel price to 2006 fuel price.
- The GWh reduction in energy sales was compared to 2018 estimates in IRP.



ENERGY EFFICIENCY
Peak reduction, scaled by load/daily peak
Residential = 6MW reduction at peak, 6am to 1am
Commercial = 4MW reduction at peak, 7am to 10pm
Resort = 7MW reduction at peak, 6am to 12am

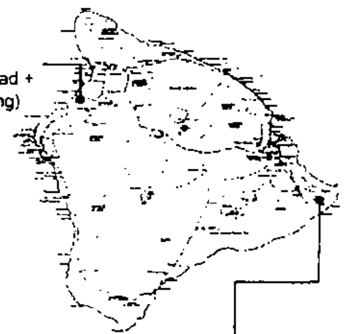
Combined Heat and Power (CHP)
Uniform 7MW reduction from 6am to 10pm

PHEV Charging (not from IRP)
Nighttime load "valley" filling based on a schedule of the previous days' peak and average load for 10% of the light duty cars. Leveraged Transportation Model.

Load Control (modified from IRP)
1MW of residential/commercial load control to reduce spinning reserve requirements.

Reduced Energy Vulnerability Scenario
Scenario Outline

Hualalai Geothermal
- 20MW of geothermal power (10MW baseload + 10MW of load following)



1. **IPP owned Hualalai & Puna Geothermal are paid a fixed price of $140/MWh at full load and $190/MWh at min load.**
2. **New geothermal plants are must-run at the minimum load.**
3. **PPAs based on avoided cost in 2018.**

Puna Geothermal Venture
- **8MW load-following, geothermal power (2MW baseload + 6MW load following)**

Hawaii Natural Energy Institute

Strategic Summary

Stakeholder Metrics

BASELINE	HIGHER WIND PENETRATION
REDUCED ENERGY VULNERABILITY	ENHANCED ENERGY MANAGEMENT

	Energy Security Imported Petroleum Reduction (%)	Environmental CO_2 Emissions Reduction (%)	Economic Ratepayer Variable Cost Reduction (%)	Economic Island Variable Cost Reduction (%)	Sustainability Renewable Energy Delivered (%)
"Baseline"	0%	0%	0%	0%	27%
"Enhanced Energy Management"	6%	6%	5%	8%	28%
"Higher Wind Penetration"	15%	14%	3%	16%	39%
"Reduced Energy Vulerability"	11%	10%	0%	13%	36%

- **In the Baseline scenario, 27% of electricity is generated from renewable energy.**
- **Energy efficiency, load control & PHEVs reduced variable cost and reduced wind curtailment. "Enhanced Energy Mgmt" results can be additive to the renewable energy scenarios.**
- **"Smarter grid" technologies needed to accommodate substantial penetration of as-available generation.**
  - **New technologies (controls, energy storage, coordinating thermal generation, etc) will be needed to enable increases in the penetration of wind power.**
  - **It is not clear how to pay for these technologies. What is the business case and regulatory support that is needed?**

Maui Project Activities: 2007 to Present

- Development and validation of electricity systems models - primarily funded by HECO with support from USDOE
  - Models currently being used for resolution of issues between IPP and HECO/MECO
- Maui Regional Distribution and Systems Integration (RDSI) project
  - Currently described as "Maui Smart Grid"

Maui RDSI Demonstration Project

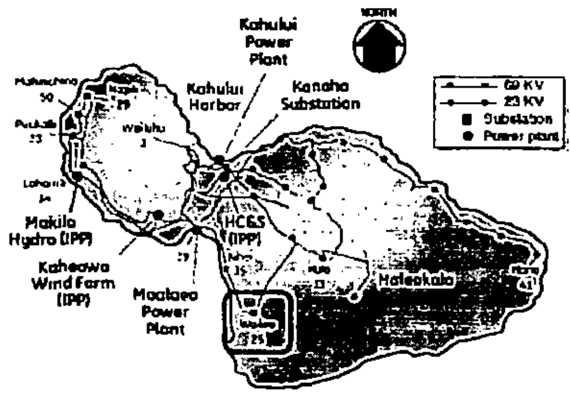
Maui Electric Company, Ltd.

Hawaiian Electric Company

Hawaii Natural Energy Institute

US Department of Energy

State of Hawaii



MAUI RDSI PROJECT: One of Nine to Win Out of 80 Proposals – **Project Objectives**

To develop and demonstrate a ***distribution automation*** solution that ***integrates dispatch of distribution assets*** (distributed generation, energy storage, demand response, renewable energy, and distribution automation) ***and bulk power assets*** (central generation, energy storage, renewable energy) to achieve system-level benefits.

- **Reduce distribution peak loading by 15% or more**
- **Improve service quality through integrated volt/var control**
- **Enable consumers to manage their energy use to minimize electric bills and utilize on-site renewable energy**
- **Support grid stability (regulating and spinning reserves)**
- **Enable greater utilization of as-available renewable energy sources**

MAUI RDSI PROJECT – Technical Challenges

Developing a *general* Smart Grid platform and architecture

- Hierarchical control – system, independent power producer, distribution microgrid substation/feeder, distributed generation and storage (conventional or renewable), customer (residential, commercial, institutional, industrial)
- Basic elements of the Smart Grid – data, sensors, communications, controllable equipment, applications (models and commands)
- Recognize that applications can run at any level, using data from any level. Applications need to be prioritized to avoid command conflicts.
- **Incorporating legacy equipment (with proprietary protocols) - interoperability**
- **Not overwhelming the system dispatcher!!**
- **Developing integrated, *secure* communications systems - cyber-security**

Maui RDSI Project - Benefits

MECO
- Improved grid stability
- Reduced use of petroleum
- Better distribution voltage management
- Incorporate more as-available renewable energy
- Integration of generation dispatch, IPP, demand response, AMI, distribution management, outage response functions
- Improved capability to effectively manage data flow for effective decisions

First Wind
- Sell more energy

Customer
- Improved service quality (voltage management)
- Lower energy bills

State of Hawaii
- Less petroleum use
- Better use of indigenous renewable energy resources
- Reduced greenhouse gas emissions

DOE
- Smart Grid architecture – solution for integrating multiple Smart Grid functions at customer, distribution, transmission, generation, IPP levels - applicable to mainland systems

Maui RDSI Project – Successes to Date

- Identified demonstration site that had to change due to economic downturn - Wailea sub-station chosen rather than proposed Maui Lani sub-station
- Data collection and model development
- Targeting utility system problems and relate to objectives of RDSI initiative
- Progress on architecture design – integration of utility (planning, operations, customer services), customers, independent power producers, vendors - Key points are:
  - Meet the requirements of the contract with DOE
  - Appropriately address the needs of the utility
  - Don't plan to just tack equipment on the system
  - Work with end-use community where possible
  - Developing solutions to meet all stakeholders' objectives

Maui RDSI Project – Where are we now?

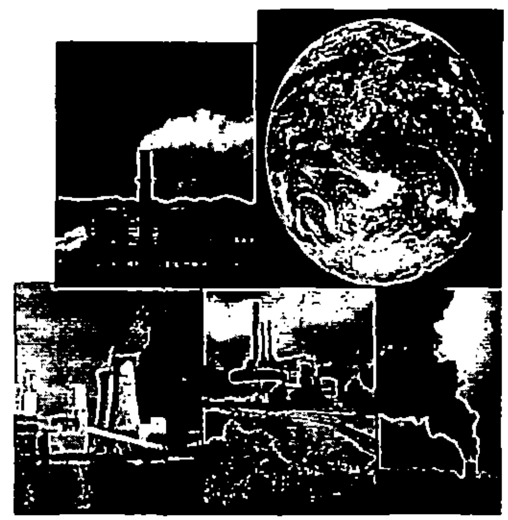
- Planning - First report will come out ahead of new schedule
  - Selecting functions, feeders, substations, customer premises, communications
  - Choosing equipment and integration/interconnection points
- Design
  - Smart Grid architecture and control hierarchy
  - Information flows and communication links
  - Functional specification of the demonstration
  - Incorporating MECO and HECO demand response, AMI, AGC, etc. functions
- Development – just starting
  - Adapting existing equipment, applications (e.g., ENMAC, wind turbine controls)
  - Developing and validating feeder models
  - Beginning development of one of the residential responsive load options – GE Residential Energy Management optimizer with smart appliances

Oahu Wind Integration Study - Current Status

- Outstanding issue is how to validate against something that has not happened.
- Models have been developed, validated and reviewed by TRC made up of national and international experts
  - Excellent team put together by Dave Corbus from NETL
- Scenario analyses are underway. Current scenarios may include
  - Scenario #1 - 100 MW of wind on Oahu
  - Scenario #2 - 100 MW of wind on Oahu and 200 MW on neighboring island
  - Scenario #3 - 100 MW of wind on Oahu and 400 MW on neighboring island(s)
  - Scenario #4 - 100 MW of solar on Oahu
  - Scenario #5 - 100 MW of solar on Oahu, 100 MW of wind on Oahu, and 400 MW of wind on neighboring island(s)

Basics for Sustainable, Secure Futures: Hawaii Can be a Leader!!

- **Environment – land, carbon, water, air**
- **Energy - security**
- **Economics – value to consumers, return on investment**
- **Equity - fairness**
- **Education – technical understanding, behavior**



Attachment B

Maui Electrical System Simulation Model Validation

Prepared for the

U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability
Under Award No. DE-FC-06NT42847
Task 9 Deliverable –
Baseline Model Validation

By

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November 2008

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Data was provided to GE by HECO and MECO for the purpose of operating under the Maui Grid Study contract. These data were used to build the models and are summarized in this report.

Table of Contents

1. Introduction

The Maui Grid Study is a joint study by Hawaiian Electric Company (HECO), Maui Electric Company (MECO), the Hawaii Natural Energy Institute (HNEI) and the General Electric Company (GE). It is one of the components of the Hawaii Distributed Energy Resource Technologies for Energy Security project.

The primary objective of this study is to develop and calibrate dynamic and production cost models for the MECO electricity grid. This is the first set of steps in an activity designed to help MECO identify technologies or operating strategies that will enable the system to manage higher amounts of as-available renewable energy. These models were validated against a base year and will be used to evaluate power system expansion scenarios for the island of Maui. This program began in January 2008 with the data acquisition and model development. This deliverable highlights the validation of the power systems model for the island of Maui.

In order to ensure the model accurately captures MECO's present system operation, the model was calibrated and validated against historical data. However, some of the operating practices that are presently in place were not in place in 2007. In order to ensure the model is useful for analysis of future scenarios, the present operating conditions were generally modeled, while only some historical operating conditions were captured. Significant iteration with the HECO/MECO team was needed to ensure the model accurately captured MECO system operation to a level of fidelity sufficient for the next phase of this study (scenario analysis of the future MECO system). Weekly meetings were organized to allow the model development and validation team to present the results from each model. Questions were asked of the HECO/MECO team to clarify system-operating practices. Based on their responses to these questions, and their inputs and directions based on questions that HECO/MECO raised, the GE team revisited the model each week, implemented the necessary changes, and presented the latest results at the following meeting. This document represents the Deliverable for Task 9, the Baseline Model Validation results. The modeling, validation, and management team is comfortable with the level of accuracy for both the GE PSLF™ and GE MAPS™ models of the MECO system for the application of these tools to system scenario analysis.

This document is intended to present the validation of databases created in GE MAPS™ and GE PSLF™ for the analysis of the electrical systems of MECO. The databases were compiled based on the data provided by HECO and MECO. These data were described in the Task 8 Deliverable, "Maui Electrical System Model Development: Data and Assumptions," the report on System Model Development. Some of the models were further improved based on the input provided by HECO and MECO after the Task 8 Deliverable was submitted. After HECO and MECO have reviewed this document, an exchange will be held to discuss the model validation and scenarios to be considered in the next task of the project.

A final comment is appropriate. This effort was primarily funded using HECO funding as part of the larger, related project that is funded by DOE. As a result, some information is considered proprietary by the utility and is presented here in this report as qualitative conclusions, although quantitative information has been presented to the utility.

2. Model Validation

The Maui grid is a dynamic system, subject to continuously changing conditions, some of which can be anticipated and some of which cannot. From a control perspective, the load and the wind power production are the primary independent variables – the drivers to which all the short-term controllable elements in the power system must be positioned and to which they must respond. There are annual, seasonal, daily, minute-to-minute and second-to-second changes in the amount (and nature) of load served by the system. The performance of the power system is highly dependent on the ability of the system to accommodate changes and disturbances while maintaining quality and continuity of service to the customers.

The modeling exercise is aimed at capturing technical aspects of challenges related to regulation, frequency control, load following and unit commitment within the transmission system capabilities associated with the present infrastructure, including intermittent resources such as wind generation. The quantitative analysis covered a broad range of timeframes, including:

- Seconds to minutes (regulation and frequency control) – Dynamic simulation,
- Minutes to hours (load following, balancing) – Dynamic simulation, and
- Hours to days (unit commitment, day-ahead load forecasting and schedules) – Production cost simulation

There are several timeframes of variability, and each timeframe has corresponding planning requirements, operating practices, information requirements, economic implications and technical challenges. Much of the analysis in the first phase of the project was aimed at quantitatively evaluating the impact of existing MECO assets, including wind resources, in each of the timeframes relevant to the performance of MECO's power system. In the longest timeframe, planners look several years into the future to determine the infrastructure requirements of the system based on capacity (or adequacy) needs. This timeframe includes the time required to permit and build new physical infrastructure. In the next smaller timeframe, day-to-day planning and operations must prepare the system for the upcoming diurnal load cycles. In this timeframe, decisions on unit commitment and dispatch of resources must be made. Operating practices must ensure reliable operation with the available resources. During the actual day of operation, the generation must change on an hour-to-hour and minute-to-minute basis. This is the shortest timeframe in which economics and human decision-making play a substantial role. Unit commitment and scheduling decisions made the day ahead are implemented and refined to meet the changing load. In the shortest timeframe, cycle-to-cycle and second-to-second variations in the system are handled primarily by automated controls. The system's automatic controls are hierarchical, with all individual generating facilities exhibiting specific behaviors in response to changes in the system that are locally observable (i.e., are detected at the generating plant or substation). In addition, a subset of generators provide regulation by following commands from the centralized Automatic Generation Control (AGC), to meet overall system control objectives including system frequency.

In the context of MECO, the infrastructure has been modeled at different levels

- Transient modeling, in the seconds-to-minutes timescale, to validate stability and transient performance of the island grid, and
- Production cost modeling, in the hours-to-days timescale, to determine the operating economics of the power system

The production model was developed in GE MAPS™. The results of the production cost model were compared to the 2007 historical operating conditions. The comparison is summarized in this report. The dynamic model was developed in GE PSLF™. The AGC model was developed to represent the MECO AGC. Three "windows" of system operation were chosen and the AGC model was calibrated and validated against these windows. This type of simulation is referred to as a long-term dynamic simulation. Additionally, transient stability simulations were performed. This included simulating load flows and contingencies in GE PSLF™ to ensure the model represented actual system behavior.

2.1 Production Cost Modeling (GE MAPS™ analysis)

Production cost modeling of the MECO system was performed with GE's Multi Area Production Simulation (GE MAPS™) software program. This commercially available modeling tool has a long history of governmental, regulatory, independent system operator and investor-owned utility applications. This tool was used to simulate the MECO production for 2006. Ultimately, the production cost model provides the unit-by-unit production output (MW) on an hourly basis for an entire year of production (GWh of electricity production by each unit). The results also provide information about the variable cost of electricity production, emissions, fuel consumption, etc.

The overall simulation algorithm is based on standard least-marginal-cost operating practice. That is, generating units that can supply power at lower marginal cost of production are committed and dispatched before higher marginal cost generation. Commitment and dispatch are constrained by physical limitations of the system, such as transmission thermal limits, minimum regulating reserve, and stability limits, as well as the physical limitations and characteristics of the power plants. Significant input has been received from HECO and MECO, and multiple model iterations have been performed, to ensure that all physical, contractual, and reliability requirements were met.

2.1.1 Model Data and Assumption

In order to characterize the operation of the MECO system in GE MAPS™, general operating assumptions were needed. It was understood by both GE and HECO/MECO that the actual operating practices vary depending on unique system events and conditions, such as the present and anticipated wind power production, the load level, the number and types of units on outage, etc. The data used in the model are outlined in the Deliverables for Tasks 6 and 7. The model data and assumptions are outlined in the Deliverable for Task 8.

To briefly summarize the Task 8 Deliverable, some of the inputs to the GE MAPS™ model are summarized below.

- Sum of hourly generation as the load profile.

- Unit characteristics, such as heat rate curve over the entire operating range Maximum power point, minimum power point, planned and forced outages rates, regulating reserve capability, and emissions rates.
- *Hourly wind power production*
- Hourly HC&S production
- System and unit constraints.
- System losses due to transmission
- General operating assumptions (described later in the report)

The unit-by-unit characteristics are summarized in the GE MAPS™ model The incremental heat rate values were compared to the MECO "ABC Heat rate Curves" to verify that the conversion was performed accurately. The fuel cost data are an input to the GE MAPS™ model These data were provided by MECO (see Table 1)

Table 1: MECO thermal plant fuel cost data ($/MMBtu) from "Power Supply Reports ('07)_031708mm.xls".

	RESIDUAL	DISTILLATE
1/1/2007	8.14	14 69
2/1/2007	8 35	16.25
3/1/2007	8 01	15 09
4/1/2007	8 43	15 82
5/1/2007	8 78	15 96
6/1/2007	8 97	17.18
7/1/2007	9 91	16 83
8/1/2007	9 91	17 52
9/1/2007	10 19	18 12
10/1/2007	10 05	17.51
11/1/2007	10 38	17 58
12/1/2007	11 32	18 92

In order to characterize the operation of the MECO system in GE MAPS™, general operating assumptions were made. It was understood by both GE and HECO/MECO that the actual operating practices will change depending on unique system events, such as the present and anticipated wind power production and load condition, as well as the number and types of units on outage, etc

The following general modeling assumptions were made

- M14, M15, M16 were modeled as operating in dual-train combined cycle mode.
- M17, M18, M19 were modeled as operating in dual-train combined cycle mode from 6 am to 10 pm
- M17, M18, M19 were modeled as operating in single-train combined cycle mode from 10 pm to 6 am
- HC&S was modeled as operating on the following schedule.
    - 9 MW from 9 pm to 7 am, and 13 MW from 7 am to 9 pm, on Monday through Saturday, and 9 MW on Sunday

- Kaheawa Wind Farm (KWP) was modeled based on 2007 hourly wind power production data (post-historical curtailment)
- K1 was modeled as operating from 6 am to 11 pm
- K2 was modeled as operating from 7 am to 10 pm
- M4, M5, M6, M7, M8 and M9 were modeled as being available from 7 am to 10 pm
- The regulation reserve requirement was modeled as
    - 6 MW plus half the power production of the Kaheawa wind farm The regulating reserve requirement calculation was changed to a new methodology in 2008
    - M4, M5, M6, M7, M8, M9, M10, M11, M12, M13, M14, M15, M16, M17, M18, and M19 were modeled as the units capable of providing regulation.
- There was no power production from Makila hydro plant in 2007, therefore, no power production from the hydro plant was included in the model.
- Outages were simulated in MAPS based on 2007 historical outage duration by unit. In future analyses it is likely that the 5-year average outage data, by unit, would be implemented in the model
- The general commitment order was obtained from MECO as K3, K4, M14/15/16, M17/18, K1, K2, M10, M19, M11, M12, M13, M8, M9, M4, M6, M1-3, X1, X2, M5, M7
    - M10, M11, M12, and M13 are interchangeable in commitment order
    - M4 and M6 are lower in the commitment order than M8 and M9 due to the limit on the operating hours
    - M5 and M7 are lowest in the commitment order due to the air permits on NOx emissions
    - M1, M2, and M3 interchangeable in commitment order
    - X1 and X2 are interchangeable in commitment order

The incorporation of these system constraints and assumptions increased the accuracy of the model with respect to the 2007 operating year This allowed the project team to compare the model results to the historical data in order to gain comfort in the implementation of the MECO system data into the GE MAPS™ model

2.1.2 Results of the Production Cost Model Analysis

Based on the validation objectives developed at the onset of this task by the HECO/MECO/GE team, the results of the model were compared to historical data The GE MAPS™ hourly production data, by unit, and a summary table, outlining the annual unit-by-unit energy production, annual production cost, annual emissions, annual fuel consumption, etc , were obtained from the model

One of the qualitative methods for comparing model results to historical data is to visually compare the hourly generation, by unit type, to historical data over a long period of time (see Figure 1) The GE MAPS™ model predicted hourly energy production similar to the historical 2007 production Some of the discrepancy between the two figures can be attributed to unit outages occurring in MAPS that did not historically occur in the same time frame Additionally, any operator intervention is not captured in the GE MAPS™ model Furthermore discrepancies between the historical system operation and the model results will be discussed later in this section This qualitative comparison allowed the project team to gauge how accurately some of the operating constraints were being implemented in the model.

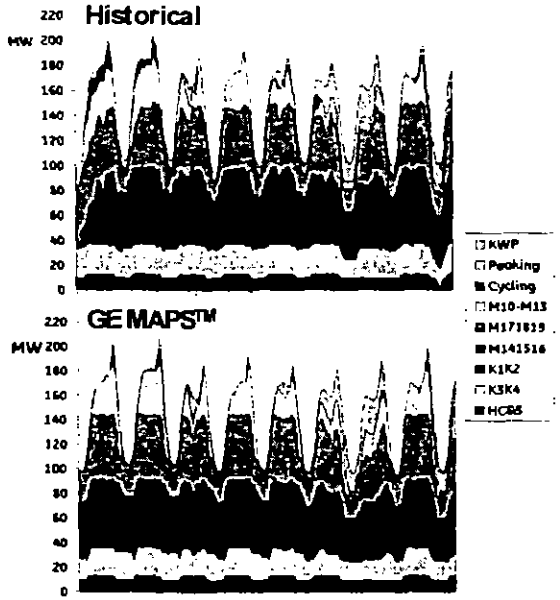

Figure 1: GE MAPS™ model results compared to historical hourly generation data for 200 hours, starting November 26, 2007 and ending December 4, 2007. The MAPS model Did not simulate the exact outage events as they historically occurred in 2007.

A number of quantitative methods for comparing the GE MAPS™ model results to the historical data were performed The first method considered the annual energy production, by unit type Since most production cost models consider units of similar type and heat rate as interchangeable, comparisons are generally made on a unit-type basis The 2007 historical energy production was chosen as the benchmark year. There are notable differences between the way MECO operated the system in 2007 and the way in which it is presently operated Both some of the present operating strategies and some of the former operating strategies were modeled in GE MAPS™, therefore, a very close

comparison to the 2007 historical year may not necessarily reflect how accurately the model would predict system operation while analyzing scenarios for subsequent years (i e , using post-2007 operating practices only) Where reasonable, the project team modeled some of the operating practices in 2007 in order to demonstrate the validity of the MAPS model to a benchmark year The annual energy production, by unit type, is shown for both the 2007 historical MECO operation and the MAPS model in Figure 2

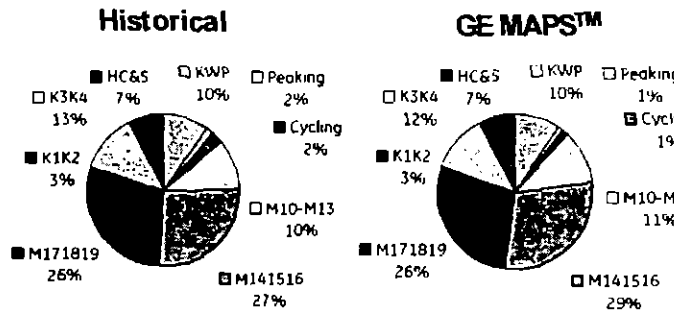

Figure 2: Comparison of the annual energy production (MWh), by unit type, between the Historical 2007 Maui energy production and the GE MAPS™ model simulation. Note that The Cycling units refers to M4, M5, M6, and M9, and the Peaking units refers to X1, X2, M1, M2, M3, M5, and M7.

Recognizing the limitations of the model, the project team was satisfied with the level of fidelity observed on a unit-by-unit basis The annual energy production, by unit type, compared within 1% of historical energy production Later in this section, the differences between the model and the historical data are discussed in further detail

The second quantitative method for validating the production cost model was a comparison between the average MECO system heat rate, based on 2007 historical data and the system heat rate obtained from the GE MAPS™ model The heat rate is calculated as the total fuel consumption on a fuel-type basis per kWh produced by those units

Based on the results of the MAPS simulation, the heat rate was ~5% less than the historical MECO system heat rate This indicates that GE MAPS™ overestimates the overall system efficiency by ~5%, similar to the level of fidelity observed in the HECO/MECO production cost simulations

The model results captured the historical energy production, by unit type and the historical system heat rate, within 5% Some of the discrepancy between the model results and the historical 2007 results can be attributed to the following factors.

- Intra-hour variability of wind/load was not captured in the hour-to-hour simulation tool. Natural imperfect dispatch of generation due to the present wind production and the wind power production trend was not captured in the model.
- The amount of regulating-up reserve available to address the decrease in wind production and increase in load varies within an hour. In the hour-to-hour simulation, the inter-hour changes in regulating reserve were not captured.
- Changes in the regulating reserve requirement may lead or lag the changes in the load and actual wind power production. For example, the amount of reserve also depends on the load level and the anticipated rate of change in load. Additionally, if the wind power is steady, MECO may decide to decrease the reserve requirements. These decisions are made at the discretion of the operator and could not be systematically captured in the model.
- After starting some units, they do not count towards the regulating reserve requirement until a specific period of time has passed. The model counts this unit in the regulating reserve requirement once it has been started.
- Differences in commitment/dispatch during outages were not captured. For example, K1 or K2 was operated as baseload when K3 or K4 was on outage.
- Temporary unit de-ratings occurred during 2007 historical operation. These de-ratings were not captured in the model.
- A detailed list of the unique operating conditions, generally not captured in production models, is provided in Docket No. 2006-0387. For example, performance tests were performed on M18 in 2007, M13 was only in operation for half of 2007 and returned to operation on July 9, 2007, and biodiesel fuel testing was performed on some of the diesel-fired units in 2007.
- HC&S was modeled on a fixed schedule, not on the actual historical production from 2007. This was done to ensure the validity of the model for scenarios.

2.1.3 Conclusions of the Production Cost Modeling

The project team agreed that the production cost model of the MECO system accurately captured the energy production, by unit type, within 1% and the system heat rate within 5%. The GE team is satisfied with the level of fidelity of the production cost model and recognizes that some of the discrepancy between actual historical production and simulate production can be attributed to a list of factors described above. The project team believes that the use of this tool to analyze system scenarios on the MECO system is appropriate for future phases of the project.

2.2 Transient Stability and Long-Term Simulations (GE PSLF™ analysis)

Transient and long-term dynamics simulations are used to estimate system behavior (such as frequency) during wind power fluctuations and system events. In combination with good engineering judgment with the understanding of the limitations of the model, this type of modeling can be used to understand the impact of transient operation of different generators on system frequency in a seconds timeframe, and can be used by utilities to ensure that the system frequency remains stable and within acceptable limits during critical operating conditions. For example, if wind power production suddenly decreases due to a sudden calming of wind in the area, another generator must increase its electricity production as quickly as the windfarm decreased its production. Depending on how fast the generator increases its production, the system frequency will deviate from 60 Hz. The dynamic simulation tool can be used to estimate the frequency excursion associated with this type of an event.

Long-Term Dynamic Simulations were performed for MECO's grid using GE's Positive-Sequence Load Flow (GE PSLF™) software. Second-by-second load and wind variability were used to drive the full dynamic simulation of the MECO grid for several thousand seconds (approximately one hour).

2.2.1 Load Flow Database conversion

The Transmission Planning Division of HECO provided load-flow databases in PSS/E format. The PSS/E datasets were converted to GE PSLF™. The comparison of GE PSLF™ results and PSS/E results was adequate and presented in the Task 8 deliverable.

2.2.2 Steady State Contingency Simulations

2.2.2.1 N-1 Contingencies in the 69 kV System

Based on the breaker locations in the single-line diagram of the MECO 69 KV system, an N-1 outage of all 69 KV lines was considered for both minimum and peak load cases. Constant power loads, generator terminal voltage control, no tap changer action and no automatic cap switching were assumed. The list of lines considered for the N-1 contingencies is given in Table 2.

Table 2: Contingency list of lines.

Outage name	Outage description
line_1	Line MAALAEA 69.0 to LAHAINA 69.0 Circuit 1
line_2	Line LAHAINA 69.0 to PUUKA 69 69.0 Circuit 1
line_3	Line LAHALUNA 69.0 to PUUKB 69 69.0 Circuit 1
line_4	Line LAHAINA 69.0 to LAHALUNA 69.0 Circuit 1
line_5	Line MAALAEA 69.0 to KWP 69.0 Circuit 1
line_6	Line LAHAINA 69.0 to KWP 69.0 Circuit 1
line_7	Line MAALAEA 69.0 to LAHALUNA 69.0 Circuit 1
line_8	Line MAALAEA 69.0 to WAIINU 69.0 Circuit 1
line_9	Line MAALAEA 69.0 to PUUNENE 69.0 Circuit 1
line_10	Line PUUNENE 69.0 to KANAHA69 69.0 Circuit 1
line_11	Line KANAHA69 69.0 to PUKLN69 69.0 Circuit 1
line_12	Line KULA 69 69.0 to PUKLN69 69.0 Circuit 1
line_13	Line KEALAHOU 69.0 to KULA 69 69.0 Circuit 1
line_14	Line MAALAEA 69.0 to KEALAHOU 69.0 Circuit 1
line_15	Line MAALAEA 69.0 to KIHEI 69.0 Circuit 1
line_16	Line KIHEI 69.0 to WAILEA 69.0 Circuit 1
line_17	Line WAILEA 69.0 to KEALAHOU 69.0 Circuit 1

2.2.2.1.1 Minimum Load Conditions

The maximum and minimum per unit bus voltages for all contingencies during minimum load conditions were evaluated and modeled, where necessary. This also includes the maximum per unit branch loading for all contingencies during minimum load conditions. One-line diagrams of the base case and the contingencies are also developed. No salient overloading or low voltage problems were observed for minimum load conditions, in line with collected information of the MECO system.

2.2.2.1.2 Peak Load Conditions

The maximum and minimum per unit bus voltages for all contingencies in the peak load case were also modeled and evaluated. Maximum per unit branch loading for all contingencies during peak load conditions and one-line diagrams of the base case and the contingencies were also developed.

The pre-contingency load flow during peak load conditions demonstrate low voltage conditions in the radial system between PUKLN69 and Hana. Any contingencies due to a line outage in the 69 kV system between Maalaea and PUKLN69 lead to either severe under voltage conditions in the radial 23 kV system to Hana or to voltage collapse.

Voltage collapse in this long 23 kV radial system was observed in N-1 outage of lines PUUNENE-KANAHA69 (line_10) and MAALAEA-KIHEI (line_15). Load flows did not solve with constant power load characteristics.

The voltage issues observed in the 23 kV system to HANA are in line with the information shared by MECO and HECO during the weekly discussions. Under system conditions that result in low voltages in Hana, MECO operators start small diesel units close to Hana.

2.2.2.2 Critical Contingencies

In addition to the N-1 contingency analysis of all 69 kV transmission lines, further analysis was performed based on the list of critical cases provided by MECO and HECO (Table 3).

Table 3: List of critical cases.

Outage name	Outage Description	Remarks
tnl-crcase-01	Lost of MPP-Waiinu line(39-636)	line_8
tnl-crcase-02	Lost of MPP-Kihei line (39-35)	line_15
tnl-crcase-03	Lost of MPP-Puunene (39-402)	line_9
tnl-crcase-04	Lost of Waiinu tie transformer (636-236) and Lost of Puunene tie transformer (4-4002)	transformer outages (N-2)
tnl-crcase-05	Lost of MPP-Lahaina (39-34) and Lost of KWP-Lahaina (97-34)	line_1 & line_6 (N-2)
tnl-crcase-06	Lost of MPP-Kealahou (39-655) and Lost of MPP-Kihei (39-35)	line_14 & line_15 (N-2)
tnl-crcase-07	Lost of KPP-Kanaha 1,2,3 (200-202,1,2,3)	lines in 23 kv system
tnl-crcase-08	Lost of Waiinu-Wailuku 23 (236-3)	line in 23 kv system
tnl-crcase-09	During minimum load, lost of KPP (K3 and K4)	generator outage

The first eight critical cases occur during peak load conditions, whereas the ninth case is during the minimum load conditions. The first three cases are identical to N-1contingency cases considered in the previous section. The corresponding contingency cases are shown in the remarks column. Case 4 is an N-2 outage of transformers, and cases 5 and 6 are N-2 outages of lines. Cases 7 and 8 are N-1 outage of lines in the 23 kV system.

Case 9 is loss of K3 and K4 units at KPP during minimum load conditions. The total amount of lost generation due to the loss of units K3 and K4 is re-dispatched on the three CT units in service during minimum load conditions, which are M14, M16 and M17. This is associated with priority levels in regulation function of the AGC application in EMS. Each of the three units picks up a fraction of the total lost generation, proportionally to the amount of its reserve. The percentage of the lost generation each of the three units picks up is as follows: M14 27%, M16 27% and M17 46%.

The maximum and minimum per unit bus voltages for all critical cases were evaluated as were the maximum per unit branch loading for all critical cases and the one-line diagrams of the base case and the contingencies. Cases 2 and 6 did not converge due to low voltages in 23 kV radial system to Hana, as described in the previous section.

2.2.3 Dynamic Contingency Analysis

2.2.3.1 Critical Clearing Times

Dynamic contingency analysis was performed on the critical cases provided by MECO (Table 3). According to the information provided by MECO, typical clearing times for zone 1 faults are between 6 to 9 cycles, and typical clearing times for zone 2 faults are 20 to 50 cycles, depending on the line. Based on this information, four clearing time combinations were chosen for the dynamic contingency analysis.

Angle stability is maintained in all critical cases for the first three clearing-time combinations. The last clearing-time combination (150ms-833ms) leads to loss of synchronism for the critical cases 1,2,3,5 and 6. Critical case 6 leads to very low voltages in the radial system between PUKLN69 and Hana.

Loss of KPP in case 9 leads to a minimum frequency of around 58.5 Hz and results in under-frequency load-shedding operation. Loads at KIHEI B, PUKLN A, LAHAINA1 and NAPILB12 (11.6MW) trip at 58.7 Hz. Many other loads would trip at 58.5 Hz.

2.2.3.2 Definition of Contingencies and Clearing Times

Based on the critical clearing-time calculations of the previous section and after further consultation with MECO and HECO, contingency cases were chosen and analyzed. Critical case 2 does not present transient instability. However, even though the simulation reaches a stable steady state after the fault, the system is likely to evolve to significant load disconnections due voltage collapse. In the transient simulations it can be observed that reactive power and the field current in MPP units are high and sustained for many seconds. There is significant risk of these units experiencing reduced field current due to over-excitation limiter (OEL) operation and consequently further reducing voltages. In case OEL limiters are not available in the units, the units may trip on over-excitation protection. This situation is also aggravated by the OLTC operation that tends to increase the load consumption of active and reactive power during low voltage conditions in the 69 kV system. Critical case 6 does not present transient instability, but would result in voltage collapse.

2.2.4 Governor/Turbine Models

Historical data of a fault at a 23 kV system on March 15, 2008 was provided to verify that the proposed governor models are representative of the performance of the different turbines. The event was recorded on the MECO system on March 15, 2008.

The data (unit power output) is sampled every 4 seconds. The sampling data are less than optimal for capturing the dynamic performance of governor response in detail. The steady state and slow dynamics response of the governor models were improved based on the historical data.

A frequency excursion similar to the EMS recorded signal was imposed to the governor and generator models of the different units in service. The simulated electrical power was used to compare the performance of the model and the recorded data.

Modifications were made to the database reported in the Task 8 Deliverable, mostly on droop settings. Most salient changes are:

- Unit K4 is less responsive than initially reported (governor with 10% droop). Due to 4 second sampling data it is not possible to differentiate between accelerating power and potential operation with dead band. It is evident, however, that there is no significant change in steady state power output during operation at 0.8 Hz above nominal. This unit will be assumed not to perform any significant contribution to primary frequency control. The same assumption will be made for K1, K2 and K3.
- The droop of unit M6 was increased from initially assumed 4% to 5.5% (5.6 MW base). The same will be used for M7 and M9.
- The droop of unit M11 was increased from initially assumed 4% to 4.5% (11.5 MW base). The same will be used for M11.
- The droop of unit M13 was increased from initially assumed 4% to 5.5% (11.5 MW base). The same will be used for M12.
- The droop of unit X2 was increased from initially assumed 4% to 10% (2.5 MW base). The same will be used for X1.

2.2.5 Steam Turbines on Combined Cycle Plant

Based on historical data sets for AGC validation, the models of the steam turbines in combined cycle were modified from previously reported models. System frequency, CTs and ST power output recorded on February 11 2008 were modeled. The ST output smoothly follows CT operation. At the time the frequency reaches 59.9 Hz, there is no transient increase of ST power. Similar behavior is observed in other combined cycle (M17, M18 and M19) and in other periods of recorded data. It can be concluded that both combined cycles operate with steam turbine admission valves fully open. The parameters for these models are different if the heat recovery steam generator has one or two CTs in service.

2.2.6 AGC Model Improvement

Different windows of historical data were evaluated with MECO and HECO. The list of data periods is presented in Table 4. The three windows highlighted in yellow were selected for the purpose of improving the AGC model. The main and challenging objective of this section is to understand the natural response of the system without operator action in the time frame of minutes, where AGC is most relevant.

Table 4: List of windows for AGC model improvement.

Date	Time	General Conditions	Notes
1/18/2008	0830-1030	Morning Ramp	M19 not on AGC while being step loaded up during event
2/3/08	2100-2300	High Load	Unit shut down during KWP drop. Good wind power fluctuation Modest frequency fluctuation M12 seems to be manually ramping down during relevant part of the recording HC&S does not seem to respond with droop, origin of power variations is unknown
2/6/08	0900-1100	After Morning Ramp	Units Started - Good wind power fluctuation Considerable frequency fluctuation. Seems to trigger assist mode in AGC M10 and M11 seems to react to AGC asset mode request M11 seems to be limiting (operations commented the fact that due to torsional concerns the units is limited) Various unit starts after frequency drop
2/7/08	0430-0630	Low Load/Morning Ramp	Units started late in event. Good wind power fluctuation Modest frequency fluctuation KPP seems to be manually ramping up during relevant part of the recording
2/11/08	1630-1830	High Load	Units started late in event. -Good wind power fluctuation Modest frequency fluctuation M13 seems to be manually ramping up during relevant part of the recording. Hard to differentiate from "natural system" response
2/11/08	2000-2200	After Peak	Good wind power fluctuation Modest frequency fluctuation M10, M11 and M13 seem to shortly react to AGC asset mode request K2 and HC&S seem to respond to manual operation
2/29/08	0430-0630	Morning Ramp	Fast Drop off, units started. Window was provided earlier for validation Good wind power fluctuation Significant frequency fluctuation CTs are only units reacting to AGC request K3 and K4 manually pick up power Several units manually started outside box
5/1/08	1245-1315	Loss of HC&S	HC&S drops more than 15 MW in about 100sec. Comparatively fast frequency drop with UFLS operation. AGC seems to enter asset and emergency modes. M5 response is reducing power before the event without clear reason

The block diagram of the AGC model was already presented in the earlier report. The historical data were used to set or confirm the parameters of the AGC model. The priority levels of the different units on AGC are presented in Table 5. Parameters of PSLF models were modified to better represent the behavior of the actual system. Several iterations were done to tune the parameters in a way that had acceptable results with the same model for three selected windows.

Table 5: Units under AGC control and priority levels.

Bus	Unit	ID	ID	Priority
106	MGS-458	4	M4	2
106	MGS-458	5	M5	3
106	MGS-458	8	M6	3
107	MGS-679	6	M7	3
107	MGS-679	7	M8	3
107	MGS-679	9	M9	3
108	MGS-1011	0	M10	2
108	MGS-1011	1	M11	2
109	MGS-1213	2	M12	2
109	MGS-1213	3	M13	2
301	CT-1 M14	1	M14	1
302	CT-2 M16	2	M16	1
304	CT-3 M17	4	M17	1
305	CT-4 M19	5	M19	1
303	ST-1 M15	3	M15	
306	ST-2 M18	6	M18	
101	KGS-1	1	K1	Basepoint
102	KGS-2	2	K2	Basepoint
103	KGS-3	3	K3	Basepoint
104	KGS-4	4	K4	Basepoint

2.2.6.1 Window 02/29/2008

The project team selected the 02/29/2008 validation window as the first window to validate. In this window, the units initially in service are:

- Wind Farm
- K3 and K4 (did not respond to frequency fluctuations)
- M14, M16, M15, M18 and M19. M16 power output is flat as the recording is from before the controls upgrade.
- HC&S (did not respond to frequency fluctuations)

The main disturbance to the system is the wind power fluctuation that was imposed in the simulation. CTs are performing all regulation. Frequency excursions do trigger a few normal to assist mode transitions in the AGC. After the shown data, units were manually started. This window assisted the project team in setting AGC regulation gains for ACE and ACE integral as well as pulsating logic for CTs.

2.2.6.2 Window 02/11/2008

The project team selected the 02/11/2008 validation window as the second window to validate. In this window the units initially in service are:

- Wind Farm with significant variations.
- K2, K3 and K4. K2 was manually ramped down
- M10, M11 and M13. Units are very responsive
- Both combined cycles are in service. M16 responds to AGC regulation requests

- HC&S. Generation did not seem to respond to frequency The power output also had some oscillations that were most likely related to steam generation/use in the plant

The main disturbance to the system is the wind power fluctuation that was imposed in the simulation HC&S was also imposed in the simulations because the fluctuations of the power output cannot be controlled directly by the MECO operators CTs and large diesels performed regulation. Frequency excursions trigger a few normal to assist mode transitions in the AGC

Unlike the prior window, the large diesels were in service (M10, M11 and M13). These units are set to priority level 2 in the AGC and operate in Assist/Emergency Mode It can be seen from the recording that once the frequency error is large enough to cause a normal-to-assist transition, these units react aggressively to recover system frequency. The AGC parameters associated with Assist mode and the pulsating logic of M10, M11 and M13 were improved, based on this recording In the recording, M10 reacts somewhat differently than M11 and M13 This difference was discussed with the HECO/MECO team There is no known reason for the differences The most relevant characteristics of the response are similar among units and well represented in the proposed simulation model.

2.2.6.3 Window 05/01/2008

The project team selected the 05/01/2008 validation window as the third window to validate. In this window the units initially in service are:

- Wind Farm with modest variations
- K2, K3 and K4 were manually operated
- M1, M2 and M3. The sum of the three units was provided in the recorded data. These units were ramped up manually.
- M5 The power output does not fully respond to expected regulations request
- M10, M11, M12 and M13. Units are very responsive.
- X2. Unit was manually ramped up
- M16 was out of service; all other units in combined cycles were on line
- HC&S Dropped about 20 MW in about 150 seconds

The main disturbance to the system is HC&S power reduction. The 58 7 Hz UFLS stage operated In the simulation, HC&S and units manually operated were imposed.

There are a few challenges associated to this window

- HC&S switched from exporting to importing power during the window. After the HC&S switched from exporting to importing, only 1-min data were available Most of the system dynamics are exercised in less than a 100-second period, where HC&S power drops from +7 to -7 MW During this period, there are insufficient measurements to characterize the HC&S variation Additional data points were added to the recorded measurements, assuming that HC&S decreased power production at a constant MW/sec rate until it reached its lowest value This assumption is closer than assuming linear interpolation between every 1-minute sample
- Many units reacted about 5 to 10 seconds before HC&S dropped, causing these units to increase power production (i e , they appeared to "anticipate" HC&S's dropping out). In discussions with MECO/HECO, it was confirmed that small synchronization inaccuracies between signals could be expected. This result had a significant effect in the frequency excursion observed in this window. These synchronization inaccuracies were less relevant for slower frequency excursions observed in previous windows
- M12 and M13 increased power before the 100 sec in recordings. The frequency at that time was not significantly off nominal to justify this power increase in these units
- M11 does not seem to modify power according to an AGC request It can be seen that the unit reduced power at around 400 sec even though the frequency is still below nominal after the event.

This historical window did not necessarily help in improving the simulation model, but showcased the model's ability to recreate this event within the mentioned limitations

2.2.7 Conclusions of the Dynamic Modeling

Various aspects of the system behavior were addressed with PSLF modeling The load flow database was successfully converted from the HECO planning tool The steady-state contingency analysis of the system presented conditions with voltage challenges in the 23 kV radial system out of Pukalani These simulation results were confirmed by HECO/MECO as similar challenges in the actual system operation Transient simulation models of fast system events (faults and generation trips) were also setup Critical events were simulated as a baseline for future scenario analysis To the extent possible using available data, governor model parameters were improved based on historical data of 03/15/2008 The validation windows of historical data were used to tune the AGC model parameters. The resulting system model (AGC, governors, generators, network, etc.) captures the relevant dynamics of the actual system in the recorded data The project team believes that the fidelity of these dynamic models is of sufficient quality to be used in the subsequent phase of this study

Attachment C

Summary Report on Stakeholder Workshop

Prepared for

U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability

Under Award No. DE-FC-06NT42847
Task 1. Deliverable #2 –
Summary Report on Stakeholder Workshop

By

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November 2007

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GE Global Research

Hawaii Roadmap Phase 2

Strategic Energy Roadmap for the Big Island of Hawaii

A Presentation of the Transportation and Electricity Modeling Analysis and Results,
and
A Summary of the inputs and outcomes of the Stakeholder Summit

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GE Research 5125 022

Table of Contents

Background

Hawaii must make decisions about its energy future. Ideally, energy should be abundant, reliable, affordable, environmentally friendly, emissions-free and petroleum-independent. However, these characteristics really represent trade-offs, for example, a highly reliable system costs more, and a balance must be struck between the costs of increasing the reliability of energy supply versus the costs (economic, social, and public health and safety) of not having energy when it is needed. Deciding on this balance is critical for the State. Such a debate depends upon having accurate assessments of the effects of energy technology, policy, and design choices. New technologies in renewable energy, energy use, energy conversion, transmission, and storage offer opportunities to provide clean, reliable, and secure energy for Hawaii at less cost. ***The purpose of the Hawaii Energy Roadmapping Study is to provide Hawaii with the capability of objectively evaluating its energy options and their true costs and environmental consequences***

The Hawaii Energy Roadmapping Study is an evaluation of the Big Island's future electricity and transportation energy options with respect to local goals and future world conditions from a technology-neutral perspective. The US Department of Energy (DOE), the Hawaii Natural Energy Institute (HNEI), The General Electric Company (GE), and the Hawaiian Electric company (HECO) and its subsidiary the Hawaii Electric Light Company (HELCO) have collectively provided ~$1.5M over a two-year period to fund the first two phases of this study

Transportation and Electricity Modeling

In Phase 1, the study developed an evaluation process that can effectively assess energy technologies and serve as guide to the development of energy policies. In Phase 2, the process of evaluating various energy infrastructure evolution scenarios will be used to identify programs that have the potential to address Hawaii's need for an affordable, reliable, environmentally acceptable, petroleum-minimizing energy sector.

The Electric System model consists of a *production cost* and *transient performance* model. The *production cost model* is used to help make decisions about which generators should be used to produce electricity in each hour of the day, based on the HELCO system constraints. This model provides information about the variable cost of production, emissions and other operating characteristics. The *transient performance model* is used to understand the impact of transient operation of different generators on system frequency in a seconds timeframe. Both of these models have been validated against 2006 historical conditions and deemed acceptable as a starting point for infrastructure evolution scenarios

The Transportation Model has been developed and validated against the data provided in the 2005 Hawaii Databook. The transportation fleet, fuel type and vehicle type breakdown were used in conjunction with fuel demand forecasts, fuel price projections, emissions data, and land use information to evaluate economic, environmental, and sustainability metrics. Presentations of the Transportation and Electricity model results are shown in the Appendix. A flow diagram of each model is shown in Figure 1

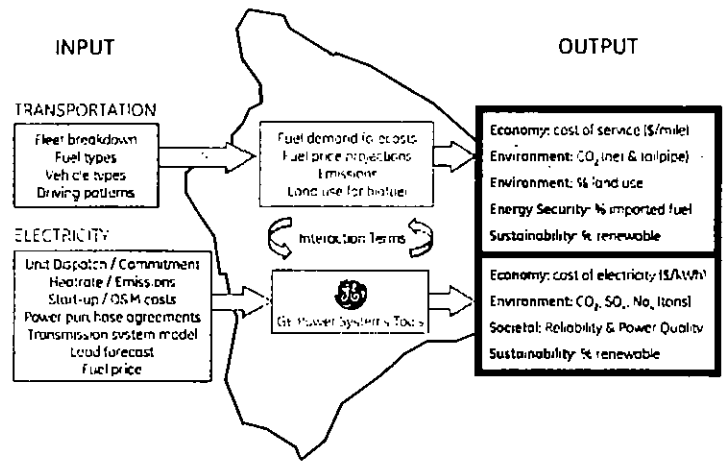


Figure 1: Hawaii Energy Roadmapping Models

It is envisioned that this validated, technology-neutral scenario evaluation tool can be used by policy makers - Local, State and Federal - to give insights and directional estimates of some of the effects of adopting candidate policies or technology strategies. The value of this is to inform discussions on the State's energy roadmap by more accurately determining the effects of energy choices on the supporting infrastructure required and the system performance metrics. Stakeholders identified the relevant metrics during a series of interviews in April and May. A presentation of the results of the stakeholder interviews is provided in the Appendix.

The complexity of energy planning can be demonstrated, as the metrics (cost, environment, reliability, oil independence, public health and safety, economic development, etc.) are often mutually competitive (increasing one metric may require decreasing the others to some extent) While tradeoffs among metrics are to a large extent a policy issue, there are also technical issues. For example, incorporation of as-available energy sources beyond a certain level can be shown to lead to unacceptable levels of system stability and energy availability unless technical mitigating measures are adopted

Stakeholder Summit

Based on the results of the electric and transportation simulation models and the concerns, preferences and suggestions expressed by the stakeholders during our interviews with them, the project team developed tools to evaluate proposed energy policies and projects in terms meaningful to Hawaii The Stakeholder Summit was an opportunity to present the results of this initial phase of the project, to explain how we intend to apply what has been learned, and to solicit further input from the diverse interests Hawaii's energy sector must serve The objectives of the workshop were

1. To present the capabilities of the energy sector models developed and the metrics to be used to evaluate energy development options.
2. To enable local (county), State and Federal policy makers to explain how they envision using this energy policy/project assessment methodology.
3. To present candidate "scenarios" that we suggest using the models to evaluate in order to exercise the models' capabilities and to provide insight into which strategies would best meet the common objectives of Hawaii's citizens
4. To try to identify potential technologies or projects that improve Hawaii's energy sector based on a consensus among a diverse group of stakeholders.
5. Finally, to obtain additional broad-based inputs on the above four items and suggestions on how governments, utilities, businesses, consumer and business groups and other organizations could advance our common interests.

An oft-repeated theme during our interviews with Hawaii stakeholders earlier this year was their desire to find ways for utilities, consumers, businesses and environmental groups to cooperate, as partners rather than adversaries, to promote clean and affordable sources of energy in the State Traditional historical roles, business strategies, and policy positions were not seen as the best ways to address Hawaii's energy issues and, as a result, were seen as also being potentially counter-productive to each stakeholder's achieving its own individual goals This project hopes to foster constructive dialog and debate on Hawaii's energy choices and, by doing so, to expedite actions, policies or projects that can be chosen by consensus to promote the general good.

Summit Results

The Department of Business Economic Development & Tourism (DBEDT), Hawaiian Electric Company (HECO), Hawaii Electric Light Company (HELCO), and many other stakeholders assembled on September 27, 2007 at the Marriott Waikoloa, on the Big Island of Hawaii. (A complete list of attendees is provided in the Appendix.) The key stakeholders were given the opportunity to make introductory statements. In the morning session, the transportation and electricity model results were presented, as well as the results of the stakeholder meetings and the scenarios chosen for this second phase of the project. These presentations are provided in the Appendix In the afternoon session, stakeholders were asked to offer their inputs, advice and suggestions to the project team Stakeholders offered comments on the overall project strategy and direction for future scenario evaluation. The following paragraphs represent a general summary of the Summit

HECO/HELCO were generally pleased with the level of detail of the model results and hope the model can be used to inform policymakers of tradeoffs in the electricity sector. The accuracy of the results of the model validation effort exceeded HECO's expectation, and HECO is looking forward to continued cooperation with the project team. HELCO would like to continue cooperating with the project team, especially since using the validated models could predict the efficacy of some of the system design, resource investment, and operating measure changes HELCO is considering in its on-going efforts to improve the electric system on the Big Island. There was general agreement that the high resolution of this tool warrants attention from the federal policymakers

The State expressed a desire to continue the GE/HNEI/HECO/HELCO partnership and to further develop and apply the tools to help State policymakers identify and quantify tradeoffs There was general agreement among the stakeholders present that the electric power model can provide answers to some of the questions the State is grappling with concerning various energy technologies, tariff and power purchase regulations, system performance metrics, and other policies. The State recognizes there are legitimate additional costs associated with connecting large amounts of wind generation to the grid (spinning reserve and/or the potential for using other technologies to mitigate intermittency). This model should be used to quantify and communicate that impact to policymakers, understanding the current program is not funded to exhaustively do this. The State is urgently trying to develop solutions to achieve lower energy prices in a world dominated by rising oil prices.

In Phase 2, for each scenario, the analysis will provide quantitative observations about the impacts of specific technology deployments on emissions, variable costs, etc While the models will not be used for detailed system design and engineering (e.g., each contingency and fault scenario cannot be considered), and the study is not designed to maximize or minimize a specific goal, the models will be used to provide directionally correct information about the impact of technology choices on the economic/environmental metrics The study cannot be exhaustive and is not intended to replace the HELCO IRP process. The project team must continue to be clear about communicating the capabilities and limitations of the model. (For example, the production cost model is capturing the variable cost of electricity production resulting from different technology deployments. It does not consider the capital costs, lifetime of equipment, rates of return, etc., although those can be separately estimated and incorporated in the assessment.)

The following list represents some of the stakeholder **opinions/comments** from the Summit:

- The model should be used to identify solutions rather than analyze problems.
- The terms of existing power purchase agreements (PPA) have locked the Island into high prices for wind power. Going forward, the terms of new PPAs must change if the island is to achieve a cost-effective renewable energy supply. It is possible that competitive bidding will reduce the prices paid to renewable IPPs in the future.
- Potential wind intermittency mitigation measures, in addition to electric energy storage, include better spillage of wind at the windfarm by the wind developer, or the use of hydro to provide the quick response needed when wind power suddenly declines. Forecasting and improved generator controls may be more cost effective than a strategy incorporating only energy storage.
- If a biofuels industry emerges there can be competition for the commodity between the transportation and electricity sectors on the Big Island.
- The increased energy security (i.e., high use of renewable energy from a very diversified technology base) should incorporate significant amounts of conservation, ocean thermal energy conversion, seawater cooling, and wave power. Such an approach satisfies the energy objectives of the island. Technology immaturity and initial high cost are two reasons high penetrations of ocean-based renewable energy technologies may not be realized by 2018.

The following bullet list represents some of the stakeholder's **suggestions** provided at the Summit. The responses are summarized in italics:

- The project team will need to identify whether the suggested technology deployments in 2018 for each scenario are achievable. *This is a necessary step to ensure the scenarios are grounded in reality.*
- A request was made to include distributed generation in the "enhanced energy management" scenario. *Distributed technologies will represent an important part of this scenario.*
- A request was made to identify and quantify the cost savings of retiring old equipment. *Because this type of analysis must be exhaustive and will require significant input from the utility, the current program is not able to provide this analysis as part of Phase 2. However, this analysis could form the basis of program activities in future portions of the program.*
- A request was made to examine the impact of revising existing/future PPAs. *Due to the parametric nature of the model, sensitivities (such as changes in the PPAs) can be considered for a scenario.*
- It was noted that the model did not consider the impacts of supply interruption on business. *Since the model is technical in nature, the model alone cannot capture these impacts, nor can it capture subjective factors, such as aesthetics and cultural impacts of certain technologies.*
- HELCO sees great benefit in understanding how much spinning reserve will be needed for additional increments of wind power. *Though this study is not exhaustive, the project team hopes to provide "directionally correct" insight into the effects of spinning reserve on additional increments of wind power.*
- HECO showed an interest in analyzing how demand side management and critical peak pricing can be a surrogate for spinning reserve. *Demand side management will be an important component of the energy management scenario.*
- The State showed an interest in understanding the impact of moderating demand and shifting demand from daytime to nighttime in the energy management scenario. *This type of analysis can be considered in the energy management scenario.*
- Natural gas can be used as a storage option to increase the island's energy security. *The storage of energy commodities, such as natural gas, has not been considered. Additional information about the impact of storage on the price of this and other commodities would be required for this analysis.*
- The stakeholders inquired about the feasibility of adding more wind power to the island. *While this study cannot exhaustively analyze the impact of additional wind power capacity, it can quantify the impact of increasing wind power both with and without mitigating measures.*

Conclusions

The input and time contributed by the various stakeholders was appreciated and adds value to this study. It should be noted that much of the model development was a result of close interaction and time spent with HECO/HELCO staff and management

The model results were presented and accepted by the stakeholders in attendance Based on the consolidation of stakeholder input, scenarios were outlined and presented at the Summit. With general stakeholder acceptance of the scenario themes outlined at the Summit, the project team has commenced more detailed scenario development based on the information and suggestions provided by the stakeholders.

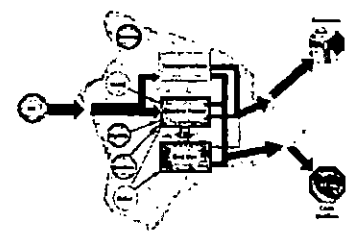
The stakeholders widely accept the objectives of this study and welcome the development of an in-state capability to evaluate policies and to better understand the systems-level impact of various technology decisions The Strategic Energy Roadmap study intends to create a technically rigorous framework to support this capability.

Appendices

Appendix B – Scenarios & Stakeholder Interview Summary (Terry Surles, Larry Markel, Devon Manz)

Hawaii Energy Roadmap

Stakeholder Input & Scenario Formulation



Terry Surles   Hawaii Natural Energy Institute
Larry Markel   Sentech, Inc.
Devon Manz   GE Global Research

Stakeholder Summit

Objectives of today's meeting

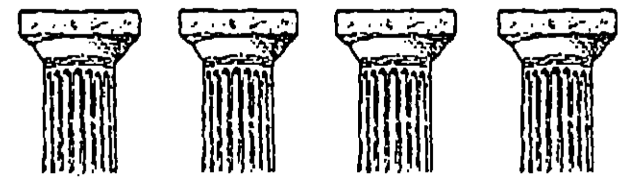
1. To **update** the assembled stakeholders:
    a. Capabilities of the **models** developed and the **metrics** used to evaluate options.
    b. To **present candidate scenarios** - developed from Stakeholder interviews
    c. **Discuss** how scenario strategies meet common *program and stakeholder objectives*
2. To enable public and private policy makers to explain how they envision using this assessment methodology
3. To obtain additional **input, advice, and suggestions** from Stakeholders on future paths for energy activities

End Result of Today's Meeting: Obtain **input, advice, and suggestions** on energy activities

1. Comments on overall project strategy and direction
   Are we on the right track, based on our earlier discussions with you?
2. Comments and direction on future scenario evaluation
   What are your thoughts on the most/least appropriate scenarios?
3. Comments and advice on additional areas to be considered
   Are we missing anything that you feel is important for the future?

Public-Private Partnerships Are Critical For Addressing Overarching Issues Facing the Nation's Energy Systems

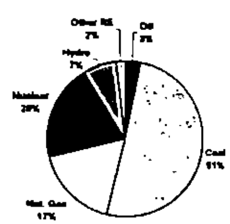
Energy System of the Future



None Of These Issues Can Be Resolved Without Partnerships - The Right Kind of Partnership Fosters Innovation for Hawaii

Electricity Generation by Source 2003 - Why we need to reduce petroleum dependency

United States



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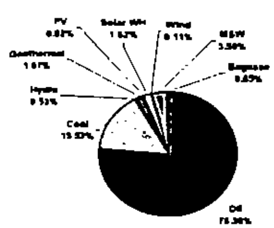
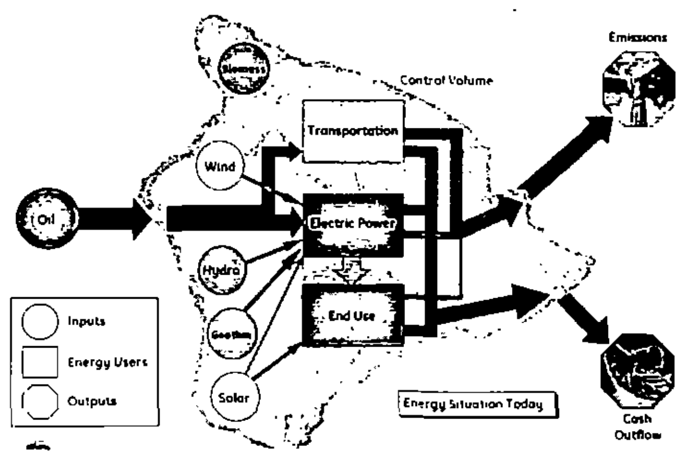
Hawaii

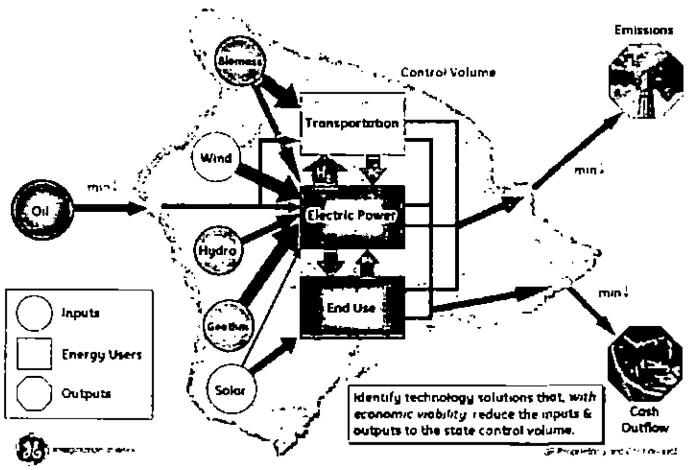


Sources: HECO and KIUC RPS Reports, FERC Form 1 or Annual Reports to PUC, and IPP reports in US EIA

DOE and State Objectives - Sustainability



DOE and State Objectives - Sustainability



Phase 1

Modeling, Validating, Calibrating - Completed

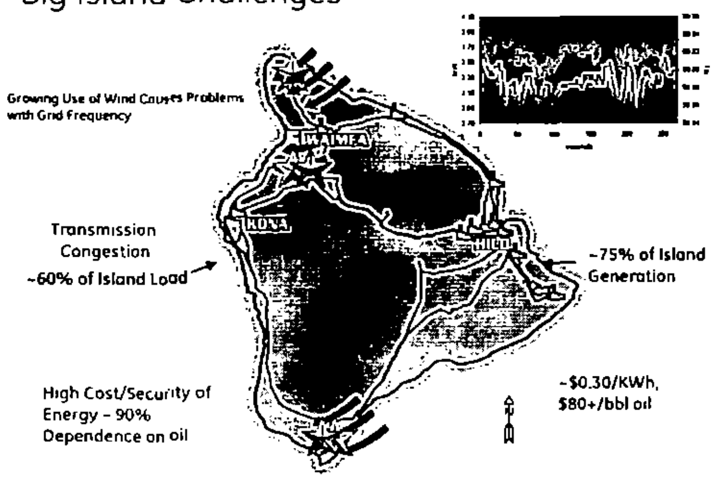
Electricity and transportation sector models describe current Big Island energy system

Models have been calibrated and validated against historical data to the high degree of accuracy required to meet project objectives

Result:

- Analytical tools and baseline for technical and economic assessment of infrastructure futures
- Can be used to establish effective parameters for future growth of the Big Island
- Tools not intended for day-to-day decision making

Big Island Challenges



Development of Better Planning Tools is a Goal Shared by All

Meet DOE mission needs

- Lessons and analytical tools for Mainland grids
- Incorporation of new technologies into grid

Address utility system planning needs

- Understand the implication of more renewable energy
- Mechanism for evaluating new technologies to address system impacts

Address state initiatives for customer benefits, public goods

- understand implications of RPS and other initiatives for reducing petroleum use
- Big Island as a potential showcase for renewable energy and the installation of innovative technologies

Phase 2
Energy Roadmapping - Just starting

Evaluate technical and economic impact of alternative energy infrastructure scenarios for the Big Island, starting from the base case

Scenarios developed based on stakeholder interviews

Continue collaboration with HECO/HELCO, state, and county to ensure model evolution is grounded in operational reality

Work with various stakeholders (i.e., government, end-users, IPPs, environmental and economic NGOs) to ensure concerns and opportunities are addressed

What does this study offer?

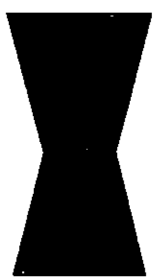
- A calibrated and validated technical, economic **and** environmental analysis of **both** the electricity and transportation infrastructures on the Big Island.
- A methodology and tool for State policymakers and utility leaders to analyze the impacts and tradeoffs of technologies and policies.
- An in-state capability to perform further energy analyses.

The ability to quantify the environmental, economic and technical tradeoffs of energy technologies and policies in the State.

A Conceptual View of the Big Island Project

We started with an expansive view of the future

We were constrained by the need to get the models right



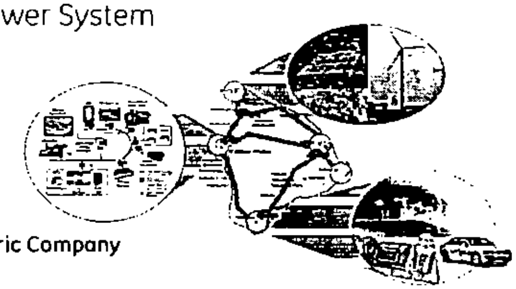
Now, we can think expansively again

Stakeholder Engagement

Appendix D – Results of the Electricity Model (Nick Miller)

Hawaii Strategic Energy Roadmap

Electric Power System



General Electric Company

Nick Miller
Gene Hinkle
Sebastian Achilles
Juan de Bedout
Devon Manz

US DOE · Hawaii Natural Energy Institute · State of Hawaii · GE Global Research GE Energy · Sentech · Hawaii Electric Light Company

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Project Approach - 50,000ft view

In Phase 1...

- The project team developed and validated a model of the HELCO system.
- The model was used to determine how incremental changes (in wind, solar, geothermal, etc) impact the cost of electricity, emissions, imported petroleum, etc.

In Phase 2...

- Four scenarios, comprised of various technology deployments, will be evaluated by the project team.
  - The stakeholders have and will provide substantial input into the scenario formulation process.
- The model will be used to evaluate the key metrics (i.e., cost of electricity, % renewable, % imported) for each scenario

What does this study offer?

- A calibrated and validated technical, economic **and** environmental analysis of the electricity infrastructure on the Big Island.
- A methodology and tool for State policymakers to help analyze the impacts and tradeoffs of technologies and policies
- An in-state capability to perform further energy analyses.

The ability to quantify the environmental, economic and technical tradeoffs of energy technologies and policies in the State.

What are the limitations of this study?

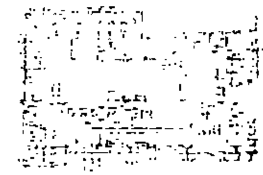
- The production cost modeling tool considers only the variable cost (fuel, O&M and start-up of each unit). In order to fully analyze the tradeoffs, additional information is needed, such as the capital cost of a technology deployment.
- The electricity model is not an exhaustive study, nor is it a substitute for utility planning (HELCO IRP).
- The model is a quantitative tool and does not output qualitative issues, such as siting, aesthetics, cultural values, etc

Electrical System Modeling

The model is comprised of two specific simulation packages

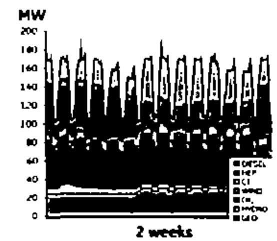
1. Dynamic Simulation (GE PSLF™)

- Transient Stability Simulation
- Long-Term Dynamic Simulation
  - Second-by-second load/wind variability driving full dynamic simulation of the HELCO grid for several thousand seconds (~1 hour)



2. Production Simulation (GE MAPS™)

- Hour-by-hour simulation of grid operations



Constructing Phase 2 Scenarios

Impact of adding:

- X MW of wind/solar/geothermal, or
- X MW of spinning reserve, or
- X MW of storage, or
- X MW of load ..

These incremental changes to the baseline model will be used to identify the impact of various technologies on achieving specific goals (i.e., How does the addition of 1MW of geothermal energy change cost of electricity?)

ON

Economy: Cost of electricity ($/kWh)

Environment. CO_2, SO_x, NO_x (tons)

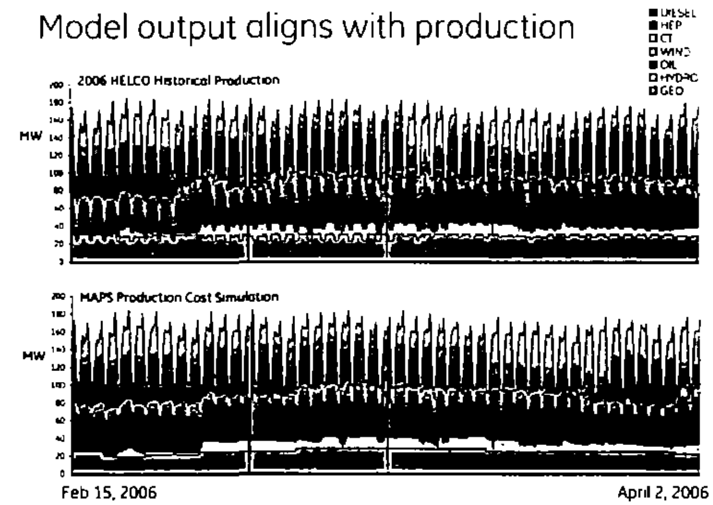
Energy Security: % imported petroleum

Sustainability: % renewable

WILL BE USED TO CONSTUCT FOUR SCENARIOS

Production Cost Modeling
GE MAPS™

Model output aligns with production



What is production cost modeling?

- Throughout the year HELCO has to make decisions about which generators should be used to produce electricity in each hour of the day.
- This decision depends on **many** constraints, including the cost of each generator, the capabilities of the transmission system, and rules about when each generator can be operated.
- **GE MAPS™**, the production cost tool used in this study, was used to simulate the HELCO production for 2006
- Production cost modeling allows HELCO to determine the cost of electricity production, emissions, etc ne

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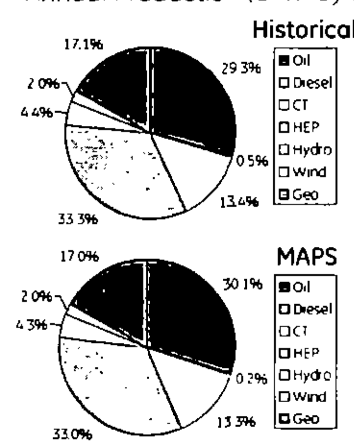
The model validates annual production

Annual Production (GWh by Fuel Type)



	GWh (2006)	
	Historical	MAPS
Oil	364	376
Diesel	6	3
CT	166	167
HEP	414	412
Hydro	54	54
Wind	25	25
Geo	212	212
Total	1241	1250

Less than 1% difference between actual annual GWh (by type) in 2006 and the results of the MAPS model.

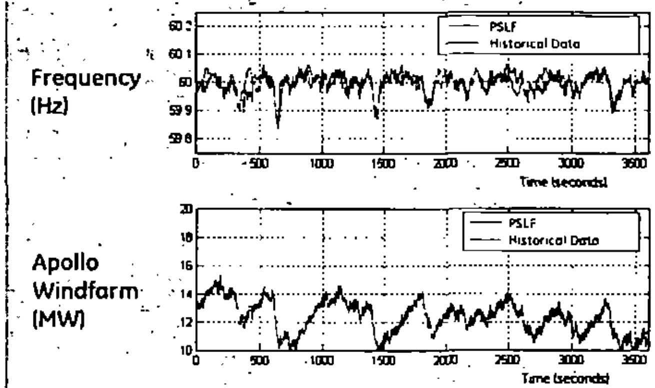
Dynamic Simulation
GE PSLF™

What is dynamic modeling?

- Dynamic (or transient stability) modeling is used to simulate the system behavior (such as frequency) during transient operation
- Dynamic modeling can be used to understand the impact of transient operation of different generators on system frequency in a seconds timeframe
- Dynamic modeling is needed to ensure that system frequency remains relatively stable during critical operating practices
  - eg. A gust of wind during the night causes a large windfarm to quickly produce additional electricity. If another generator is unable to reduce its electricity production as quickly as the windfarm picked up, the system frequency will deviate from 60Hz
- **GE PSLF™** was used to simulate HELCO operation

Model results align with historical data

Example: Significant Wind Fluctuation (04/03/07)



What are the types of analyses we can perform with this tool?

What if 1MW of wind power is added to Apollo wind farm?

		Fuel Use	Emissions (tons)		
	GWh	MMBtu	NOx	SOx	CO_2
Combined Cycle	-2.1	-15545	0	-2	-1352
Combustion Turbine	-1.3	-13905	-1	2	-1245
Diesel	0.0	-341	0	0	-29
Puna Geothermal	0.0	0	0	0	0
Small Hydro	0.0	0	0	0	0
Steam Oil	-0.6	7582	-1	-1	-726
Wind	4.1	0	0	0	0
Solar	0.0	0	0	0	0
Grand Total	0.1	37374	2	6	-3352

- With no other changes to the system, an increase in wind power offsets fossil fuel generation and reduces emissions
- But, HELCO must maintain their system frequency at 60Hz.
- Sudden changes in wind power output will affect the frequency, therefore increasing wind power requires some additional considerations.

Is there more to this story?

Cost Adders

Wind power reduces the island's carbon footprint, and reduces the amount of imported petroleum, but...

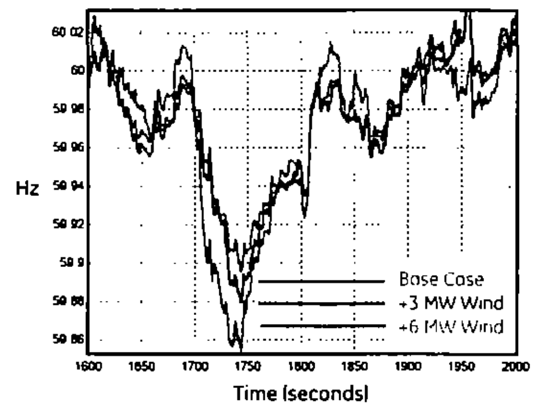
↑ 1) **More spinning reserve will be needed** - More oil must be burned so some generation is ready to quickly meet changes in the system load or wind farm output, and/or

↑ 2) **New technologies** can be used to mitigate the intermittency of wind power

? 3) **Price paid to wind producers** matters. If HELCO pays a wind producer more than it costs them to produce electricity from fossil fuel generation, more wind power will cost the island more.

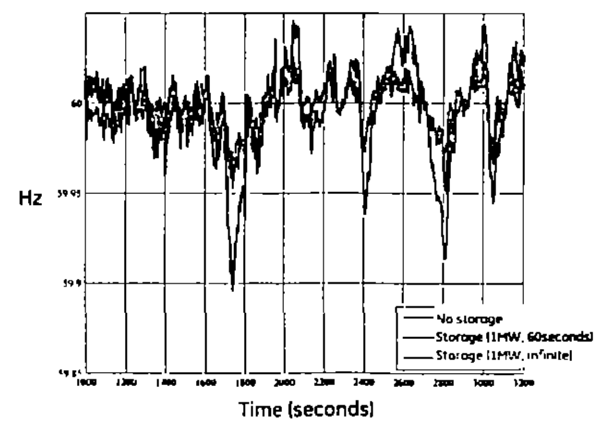
Example: What if HELCO had More Wind?

Significant Wind Fluctuation on May 23rd 2007



Example: Does Energy Storage Help?

Significant Wind Fluctuation on May 23rd 2007



Conclusions

1. GE has developed an electricity model that has validated an entire year of production based on historical data from 2006.
2. The model is capable of quantifying the environmental, economic and technical tradeoffs of incremental changes in power generation and other technologies, however this study **is not** exhaustive and **is not** a substitute for IRP.
3. The discussion of incremental changes of various technology deployments from the baseline provides direction for scenario development
4. We will be opening the floor to the stakeholders, for discussion, this afternoon.

Appendix E – Summit Participants List

Sandia National Laboratories uses Real-Time Simulation to Shed Light on the use of Photovoltaic Distributed Generation in Hawaii

Originally published
in the December 2009
issue of Planet-RT

The Hawaiian power grid is transforming from diesel to renewable.
Discover how simulation and study is helping and making engineers understand how this power grid will look in 2030

Sandia National Laboratories uses Real-Time Simulation to Shed Light on the use of Photovoltaic Distributed Generation in Hawaii

Sandia National Laboratories

Hawaii is heavily dependent on fossil fuel for meeting its energy needs. Indeed, more than 90% of the US state's power is currently generated by imported foreign oil. This has left Hawaiians paying the highest energy costs in the nation, and leaves them vulnerable to foreign political instability and disruptions in supply that could cripple the economy of the Pacific island chain.

While US mainland energy costs typically hover at approximately 4% of a state's gross domestic product (GDP), Hawaii's costs are almost triple, approaching 11%. With the recent spike in oil prices, particularly in mid-2008 when oil prices approached US$150 per barrel, the impact on the Hawaiian economy has been dramatic, highlighted by a 36% increase in Hawaiian household fuel and utility costs during the 2nd quarter of 2008.

To address this issue, the State of Hawaii has entered into a partnership with the US Department of Energy to establish the **Hawaii Clean Energy Initiative (HCEI)**, with the goal of having 30% of Hawaii's energy needs met by renewable sources by 2030.

The HCEI has been launched with a focus on three projects including ***"Lanai 100% Renewables"***. As the name suggests, the objective of this project is to assist the island of Lanai in meeting its eventual goal of obtaining 100 percent of its energy from renewable sources The shorter term goal for Lanai is to achieve 30% of power generated from renewable sources by 2030.

Currently, Lanai is served by the Maui Electric Company, while Castle & Cooke, Inc , one of the US's oldest real-estate developers, owns the majority of Lanai. The primary loads in Lanai come from two Castle and Cook Resorts, in addition to residential needs The total peak load profile is 12,470V, 5 5 MW Currently, there are several diesel generators that meet these loading requirements As part of the HCEI, 1 2MW of Photovoltaic (PV) generation has already been installed in Lanai, bringing the HECI team very close to the 30% goal in a very short time.

PhotoVoltaic cells recently deployed in Lanai

Attachment D

PhotoVoltaic cells recently deployed in Lanai

To conduct a study evaluating the impact of integrating PV with conventional carbon-based diesel generation, the HCEI enlisted the aid of Sandia National Laboratories.

Sandia National Laboratories is a US government-owned/contractor operated facility that focuses on the development and application of technologies that ensure the homeland security of the United States. Traditionally, Sandia's focus has been primarily placed on ensuring the safety, security and reliability of America's nuclear weapon stockpile. However, in recent years, Sandia's focus has increasingly turned to the development of sustainable, clean and efficient sources of energy.

Sandia engineers have faced two tasks in Lanai:

1. Ensuring that the migration to renewable energy also provided for the contingency to add additional generation capacity that could then be transmitted to other islands as part of a larger state-wide power grid.
2. Demonstrating that when the PV power plant is in operation, the implementation of effective controls reduces the need for capital-intensive energy storage systems for frequency and voltage stability.

For intermittent PV distributed generation, Sandia engineers investigated overall stability and transient responses. A simple Lanai "like" model was developed in the MATLAB/Simulink environment, illustrated in Figure 1, and an eMEGASim Real-Time Simulator from Opal-RT Technologies was used to conduct real-time simulation of the hybrid power grid system.

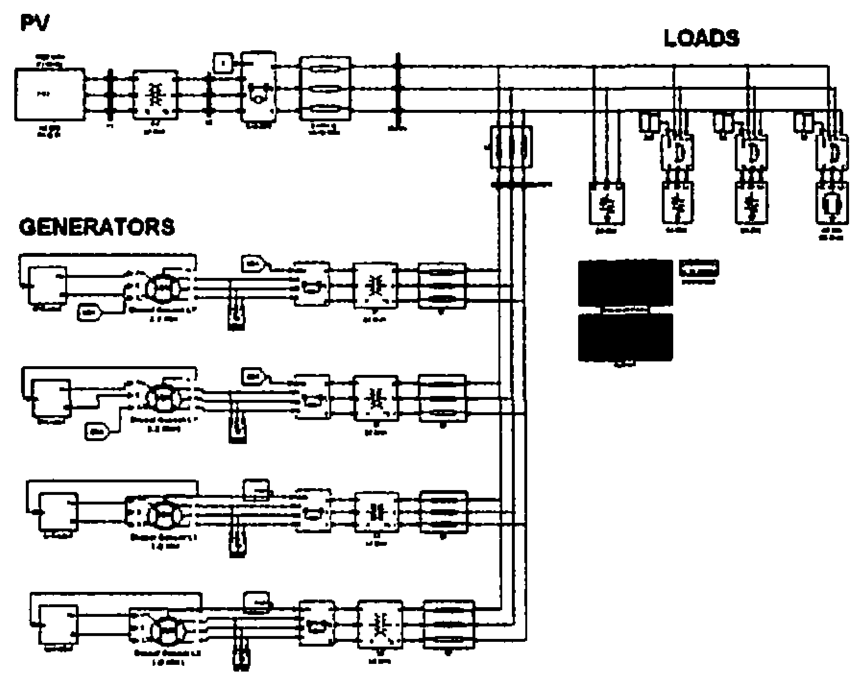


Figure 1. Lanai "like" Matlab/Simulink Power Grid Model

The diesel generators were modelled using SimPowerSystems toolbox swing equations and a custom Simulink module was developed for high-level PV generation. All of the loads were characterized primarily as distribution lines with series resistive load banks with one VAR load bank. Three-phase faults were implemented for each bus.

"The one thing we run into when adding PV to these small systems is degradation of frequency and voltage", said Benjamin Schenkman, a member of Sandia National Laboratories' technical team. "We've modelled everything in MATLAB/Simulink with the SimPowerSystems software, and so far shown found it to be stable. So, what we're trying to do is see if we need to add additional controls or add more energy storage."

The use of simulation and Hardware-in-the-Loop testing played a critical role at this stage of the study. The non-linear power flow control models needed to be simulated to ensure that they would perform adequately now, as well as pave the way for integration of future Distributed Generation devices, such as a proposed wind farm.

"What if we add wind or more concentrated solar, how will the system react? With this project, when running tests in SimPowerSystems in offline mode, you can run maybe one test per hour. To run multiple tests takes days and days and days," added Mr. Schenkman.

This is where the Opal-RT eMEGAsim simulator comes in. By using eMEGAsim, which is driven by RT-LAB, Opal-RT's Real-Time Simulation platform, and ARTEMiS, an Opal-RT solver specifically designed to enable the execution of SimPowerSystems models in real-time, the simulation bottleneck was easily overcome.

According to Mr. Schenkman, "With the Opal-RT equipment, we can actually run the simulations 100 times faster, and run tests in minutes that would normally take hours. And, the results have been dead on."

But, as is often the case with larger scale engineering projects like Lanai, nothing beats testing using physical hardware. As a consequence, Sandia conducted extensive testing at the organization's **Distributed Energy Technical Laboratory** to determine whether the positive results received with the Simulink/SimPowerSystems models remained accurate.

"Customers like to see tests done with hardware, using real generators, using real PV," said Mr. Schenkman. "So we take the Lanai grid, scale it down, take real generators, real PV. We also take the utility's model, put it into Simulink and go to our lab. We test it out in real-time using Opal-RT equipment. And then go to Lanai and say to the customer, 'this will work'."

Preliminary results for generator transient responses and PV output have been positive. Both conventional and advanced control architectures are being used to evaluate the integration of the PV onto the current power grid system.

While ahead of schedule, the work in Lanai continues. Sandia engineers still face the challenge of implementing additional non-linear power flower controls into grid models and validating these models using eMEGAsim with physical Hardware-in-the-Loop at the Distributed Energy Technical Laboratory.

For both the Sandia engineers and their customer utility, the Lanai project has been a learning experience.

"The idea of this type of study is very new for utilities," concluded Mr. Schenkman. "Using real hardware in simulations has not been their traditional approach. Utilities often just look at whether systems are balanced or unbalanced using software that is not very dynamic."

"But by using tools like SimPowerSystems and eMEGAsim, we can remove the guesswork and can see exactly what is going to happen in the future."

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I hereby certify that I have this date filed and served the original and eight copies of the foregoing **COMMENTS OF ZERO EMISSIONS LEASING LLC ON RELIABILITY STANDARDS** in Docket No. 2008-0273, by hand delivery to the Commission at the following address:

CARLITO CALIBOSO
PUBLIC UTILITIES COMMISSION
465 S. King Street, Suite 103
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I further certify that copies of the foregoing **COMMENTS OF ZERO EMISSIONS LEASING LLC ON RELIABILITY STANDARDS** have been served upon the following parties and participants by causing copies hereof to be hand delivered, mailed by first class mail or electronically transmitted to each such party as follows:

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